How to prove you know something (without saying it)

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Joint research between C4DT: Linus Gasser, Carine Dengler, Ahmed Elghareeb

And SICPA: Luca Multazzu, Darko Kulic

Plan

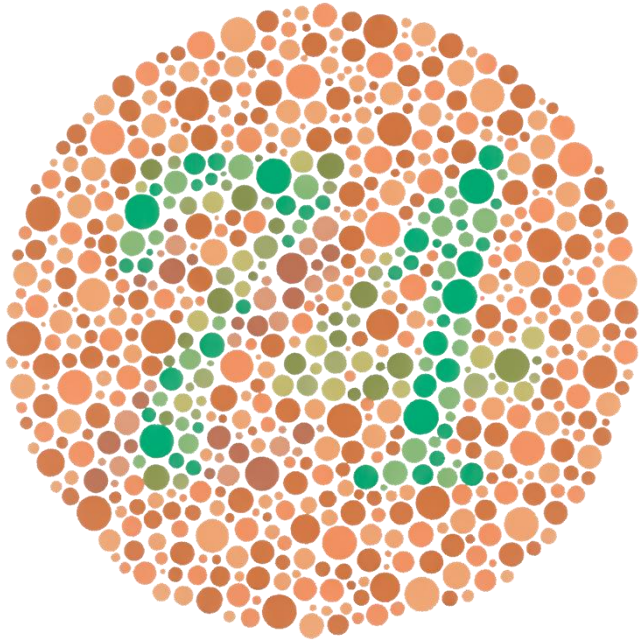
- What are ZKPs ?
- What can we do with ZKPs ?
- What are we using ZKPs for ?

What are ZKPs ?

Zero-Knowledge Poodles for dummies

“It’s magic” – and other examples

- **Colored balls**
- Cave’s password
- Where’s waldo
- Peggy’s red card



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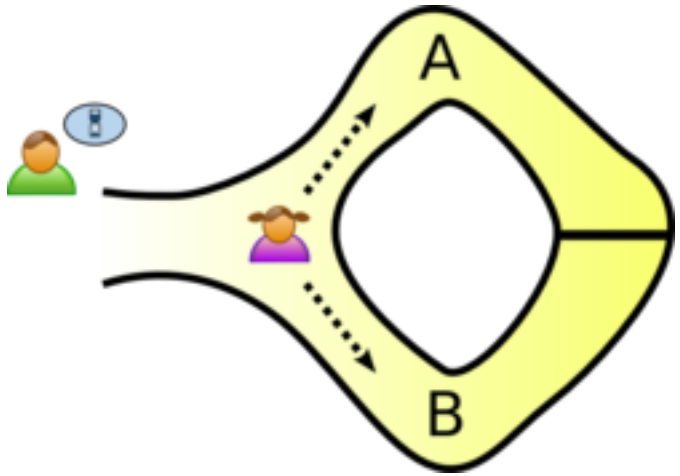

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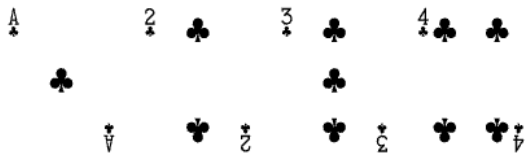

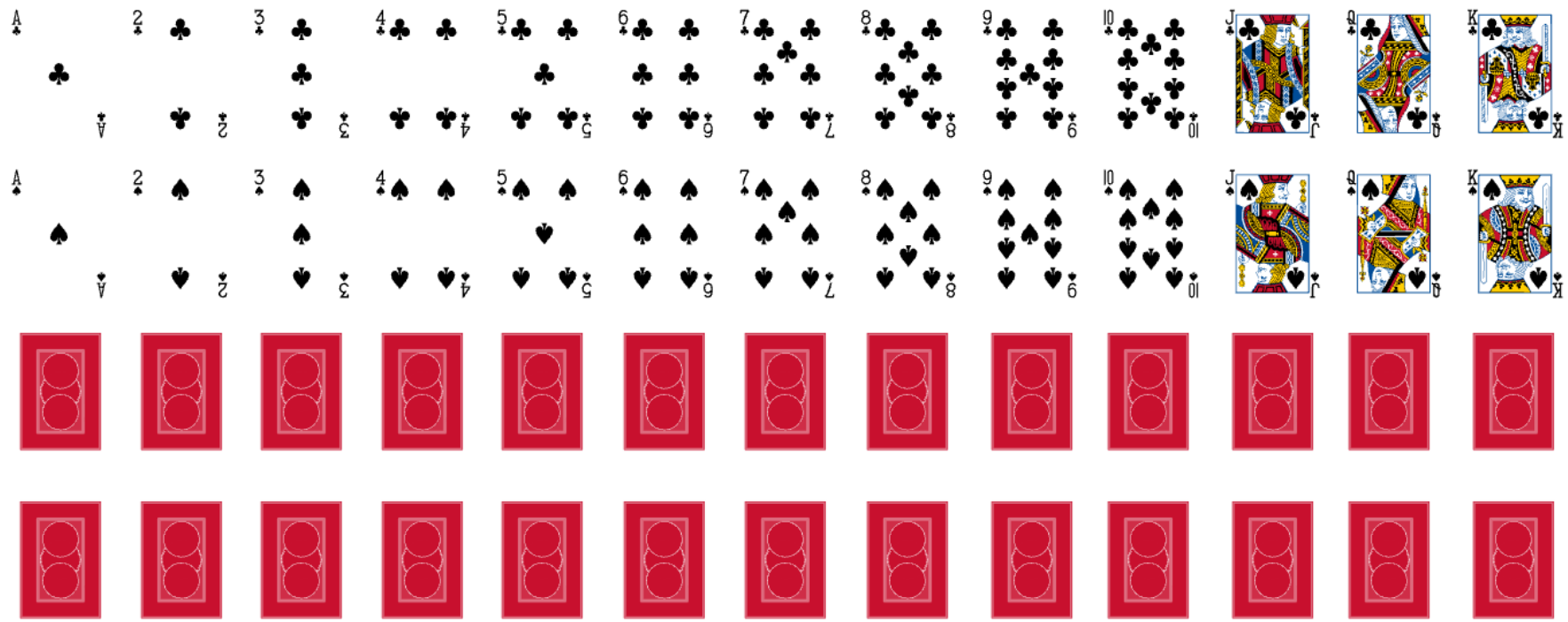

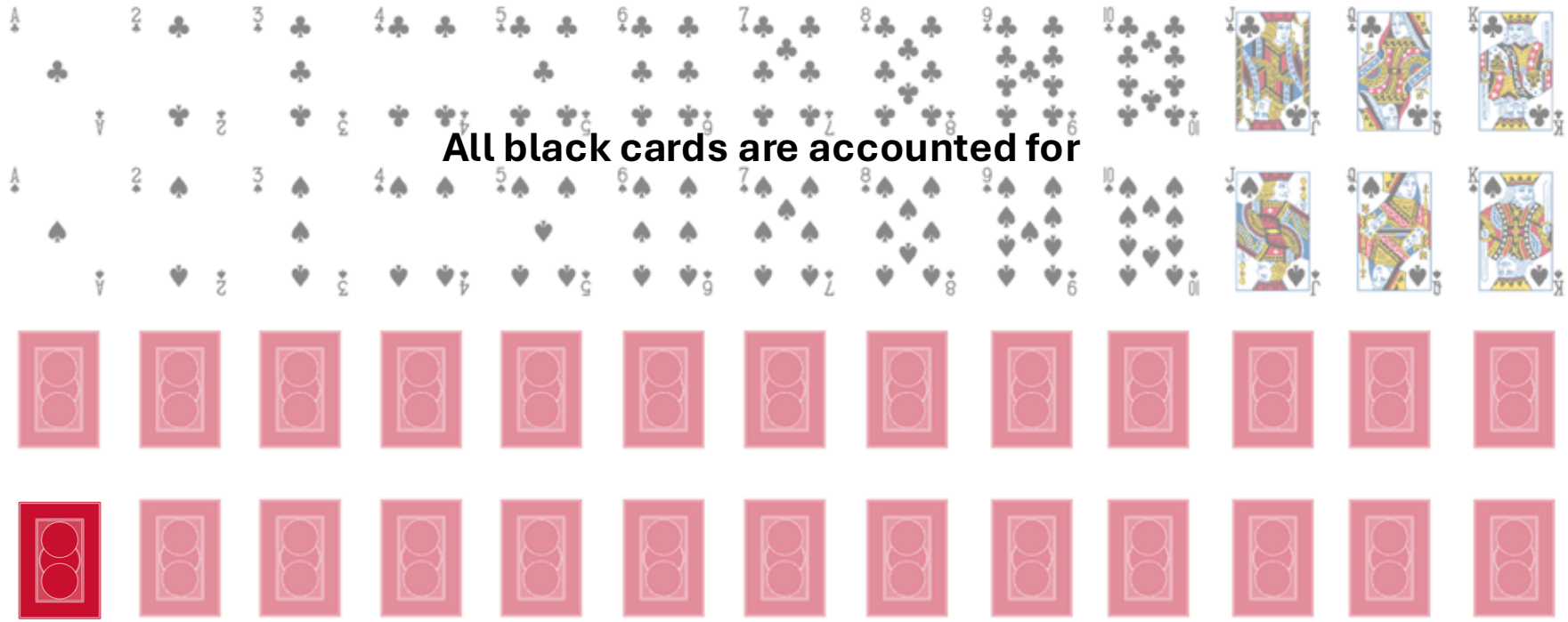
All black cards are accounted for

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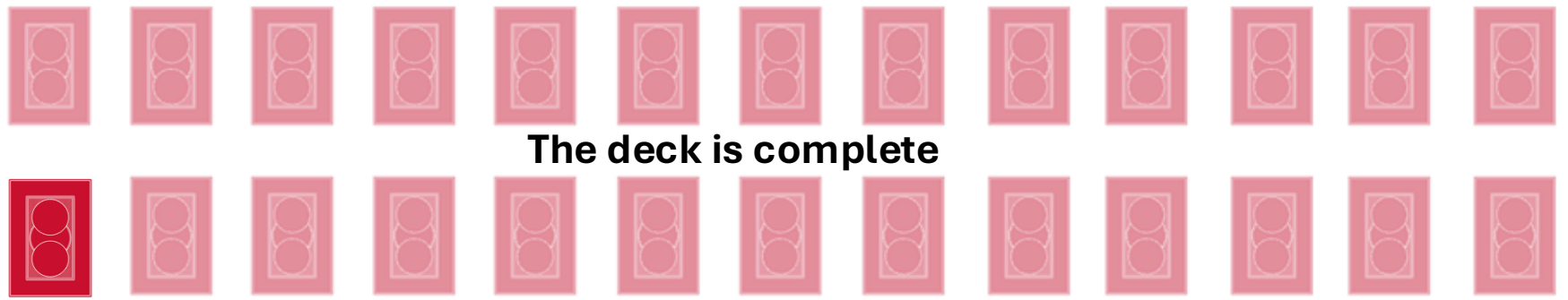
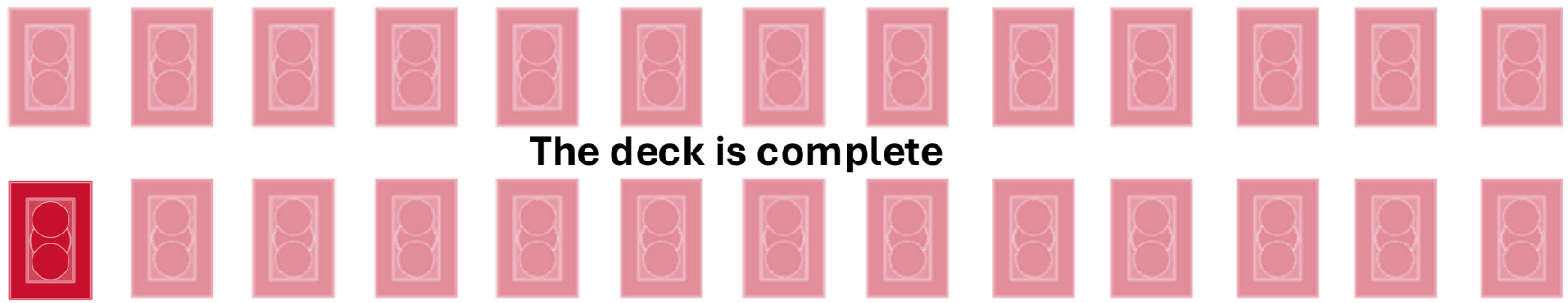


The deck is complete

All black cards are accounted for



The deck is complete

Peggy’s card is face down with the other red cards

What is a ZKP ?

A ZKP is an interactive protocol in which a prover tries to convince a verifier that a statement is true without revealing more than the statement and its truth value.

- **Completeness**: the verifier will always be convinced if the statement is indeed true.
- **Soundness**: the prover cannot produce a proof that the statement is true if it’s not.
- **Zero-Knowledge**: the interaction does not reveal more information than the statement’s truth value.

Peggy's cards properties

- **Completeness** After the protocol has ended, if Peggy has a red card, Victor can see that all the black cards in the deck have been drawn and is convinced that Peggy has a red card.
- **Soundness** If Peggy is cheating, she'll be unable to produce all the black cards for Victor to count. There's no chance she can convince Victor.
- **Zero-Knowledge** Thanks to red cards being kept face down, Victor does not learn anything more about Peggy's card than its color. This holds no matter how many time the protocol is repeated

What can we do with ZKPs ?

Collect them like they’re Pokémons

zkVMs, Smart Contracts, B[redacted]kch[redacted]n

- **ZCash** uses ZKPs to anonymize senders, recipients and transacted amount while retaining proof of validity of transactions.
- **zkVMs** are virtual machines that create a proof of correct execution for the programs they execute. Verifiers can ensure correct execution with less work than redoing the computation.
- **Transactions rollups** bundle the correctness of a bunch of transactions into a proof that requires less work for verifier.

Digital identity, digital cash, supply chain

- **Digital identity** can make use of ZKPs to allow identity-holders to prove statements about themselves without oversharing information.
- **Digital cash** can use ZKPs to ensure compliance to cash transaction regulations without compromising the privacy guarantees of cash.
- **Supply chain** can use ZKPs to prove compliance to industry and market regulations without exposing sensitive business information.

Marketing

Safeguarding cryptocurrency by disclosing quantum vulnerabilities responsibly

https://research.google/blog/safeguarding-cryptocurrency-by-disclosing-quantum-vulnerabilities-responsibly/

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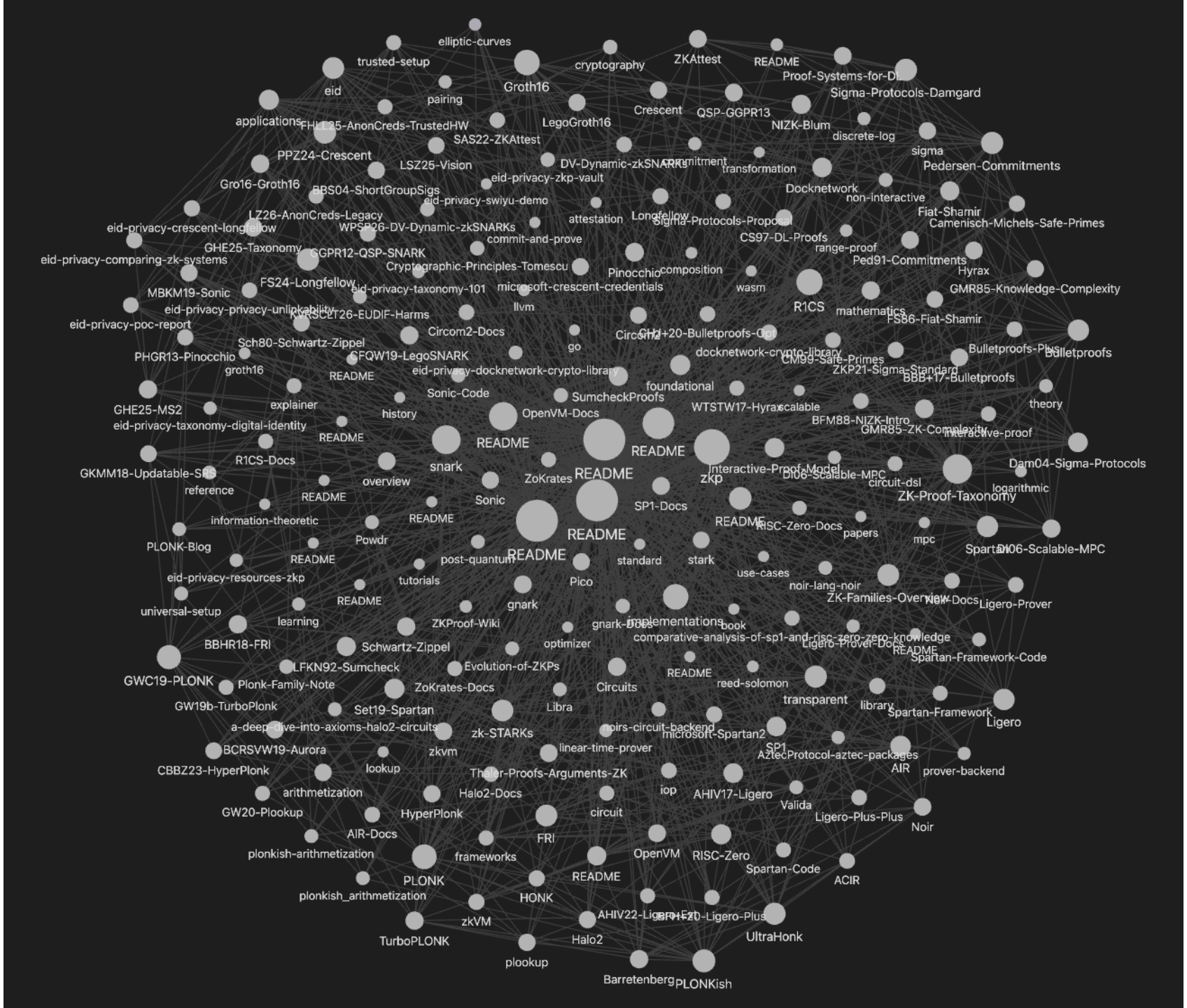
We beat Google's zero-knowledge proof of quantum cryptanalysis

https://blog.trailofbits.com/2026/04/17/we-beat-googles-zero-knowledge-proof-of-quantum-cryptanalysis/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Circomlz
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zkVM
TurboPLONK
Halo2
UltraHonk
plookup
Barretenberg
PLONKish

Limitations and frontier being worked on

- ZKPs are computing intensive, an important issue when it comes to consumer-centric use cases
- Concrete performance of post-quantum secure schemes is not ideal
- Auditability of implementations and circuits leaves to be desired
- ZKPs cannot prevent context-specific overreach

Digital identity, digital cash, supply chain (2)

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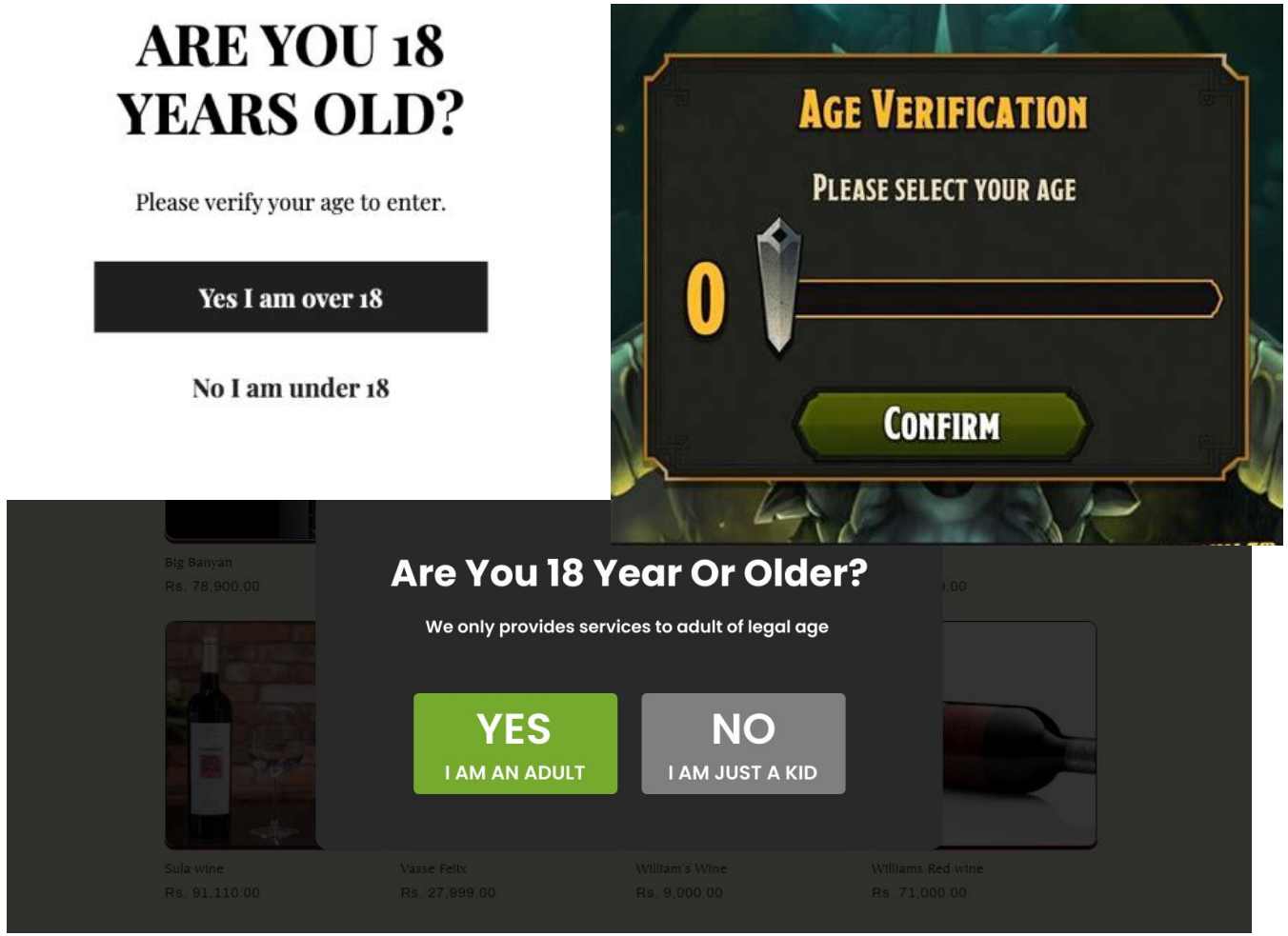
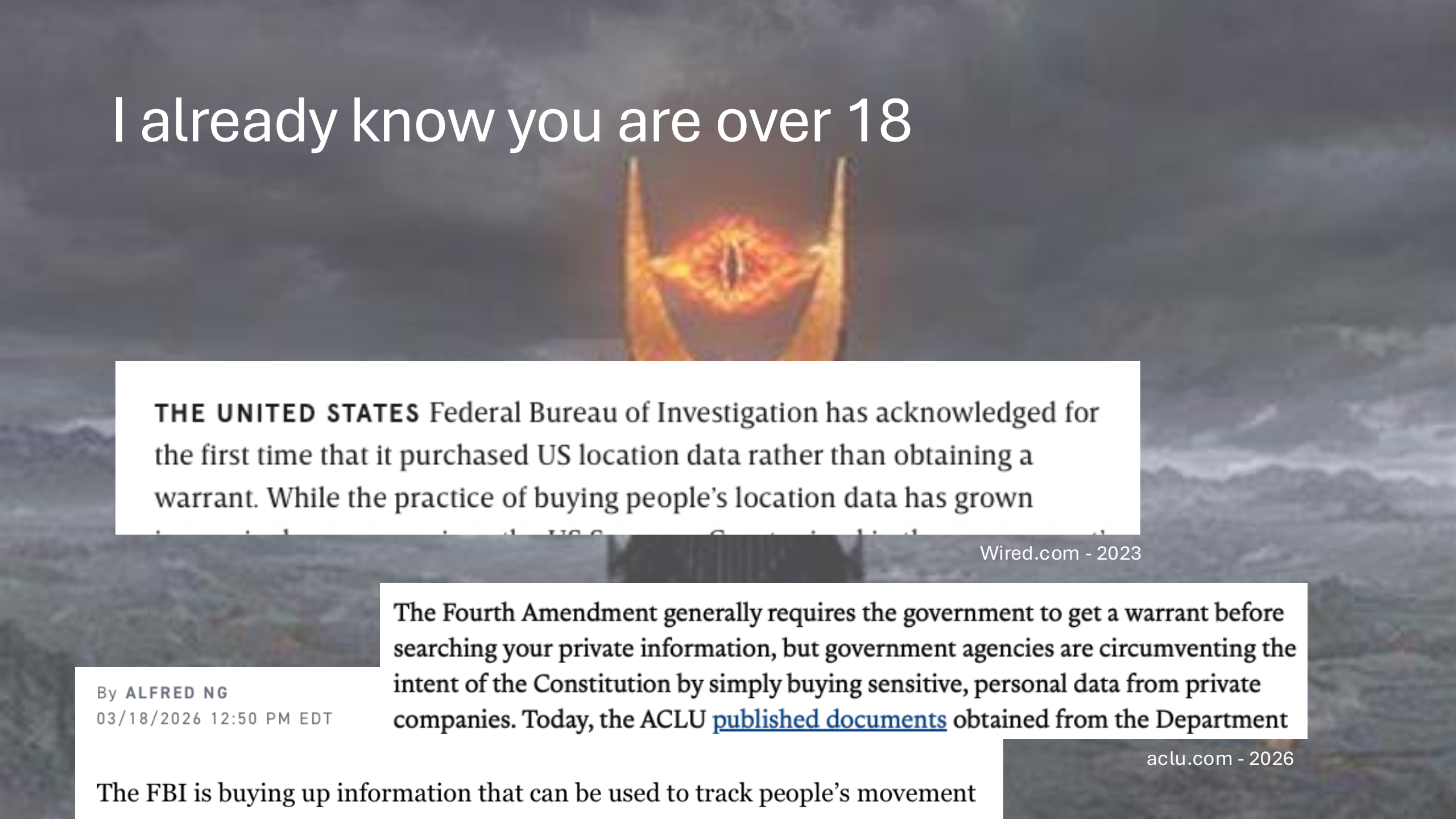
Easing the privacy vs. oversight tensions: e-ID, ZKPs, age verification

Trust me bro, I’m over 18



I already know you are over 18



THE UNITED STATES Federal Bureau of Investigation has acknowledged for the first time that it purchased US location data rather than obtaining a warrant. While the practice of buying people's location data has grown

Wired.com - 2023

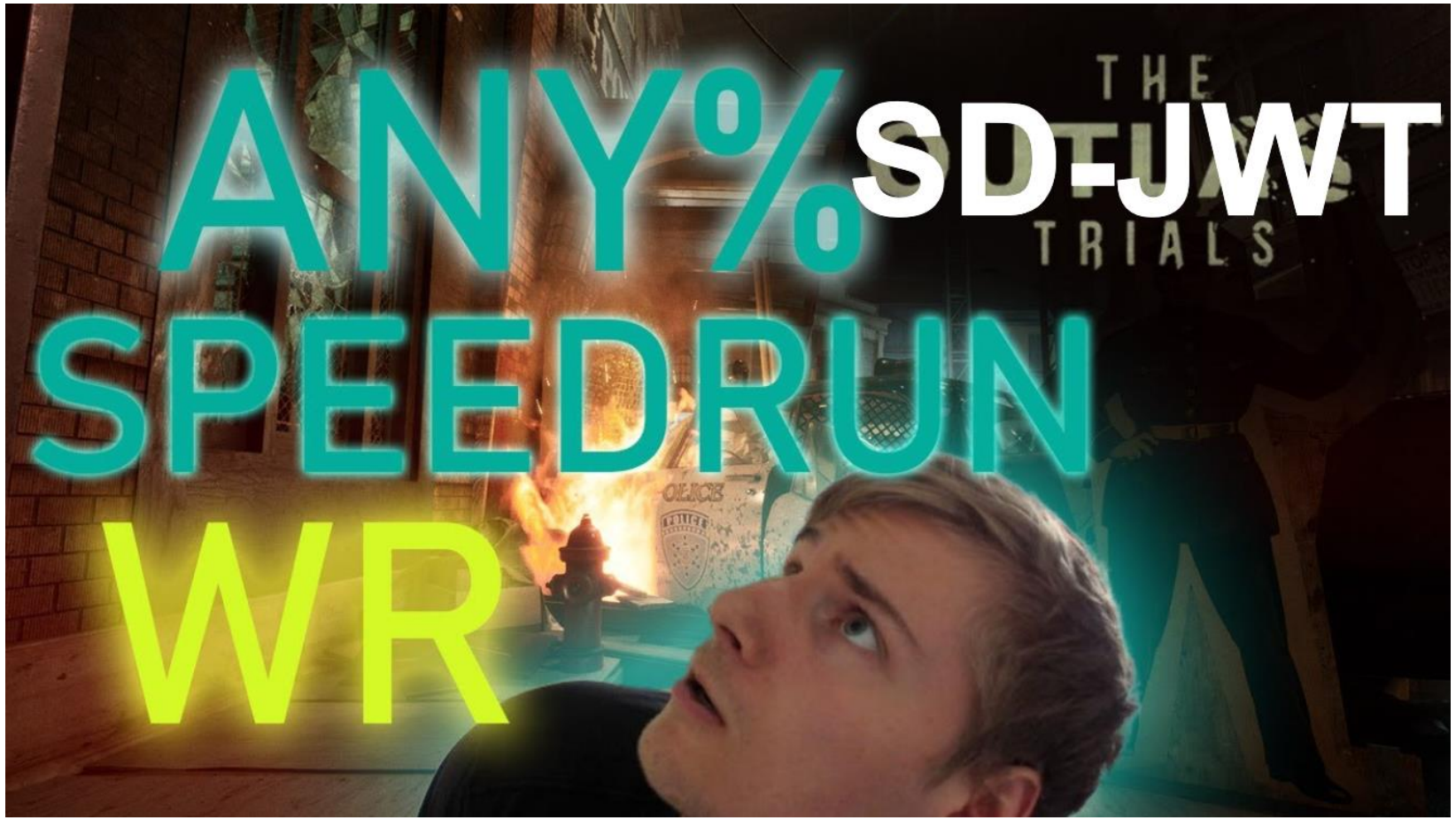
The Fourth Amendment generally requires the government to get a warrant before searching your private information, but government agencies are circumventing the intent of the Constitution by simply buying sensitive, personal data from private companies. Today, the ACLU published documents obtained from the Department

aclu.com - 2026

By **ALFRED NG**
03/18/2026 12:50 PM EDT

The FBI is buying up information that can be used to track people's movement

The Swiss E-ID


ANY%
SD-JWT
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TRIALS

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Decoded body:

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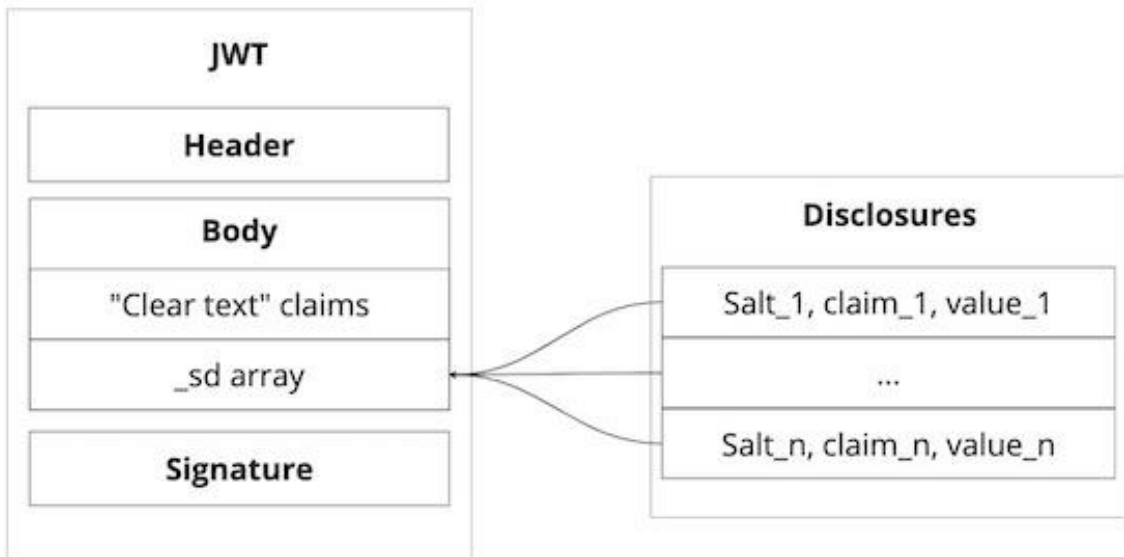



```
Disclosures:
[
    DpE9LJ2SHaR23KFuCtCSbQ, <---
    look, <--- claim name"
    duck <--- claim value"
]
[
    -JldcDGqa00ImdPUCFUvlA, <---
    quack, <--- claim name"
    duck <--- claim value"
]
```

Proving set inclusion:
"I am a Swiss citizen"

Proving arithmetic statement: "I'm over 18"

Cred. type

Signature

Information revealed with controlled impact on privacy.

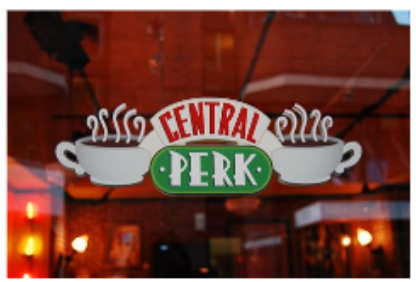
age > 18

Signature

Uniquely identifying information. Correlation is trivial.

Ville de Lausanne

~~Can~~ try to correlate information
Will



Proving set inclusion:
"I am a Swiss citizen"

Proving arithmetic statement: "I'm over 18"

Cred. type

Signature

Information revealed with controlled impact on privacy.

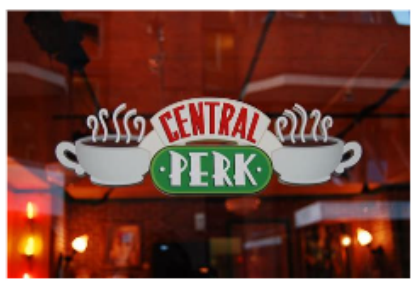
Proving knowledge of signature

age > 18

Signature

Ville de Lausanne

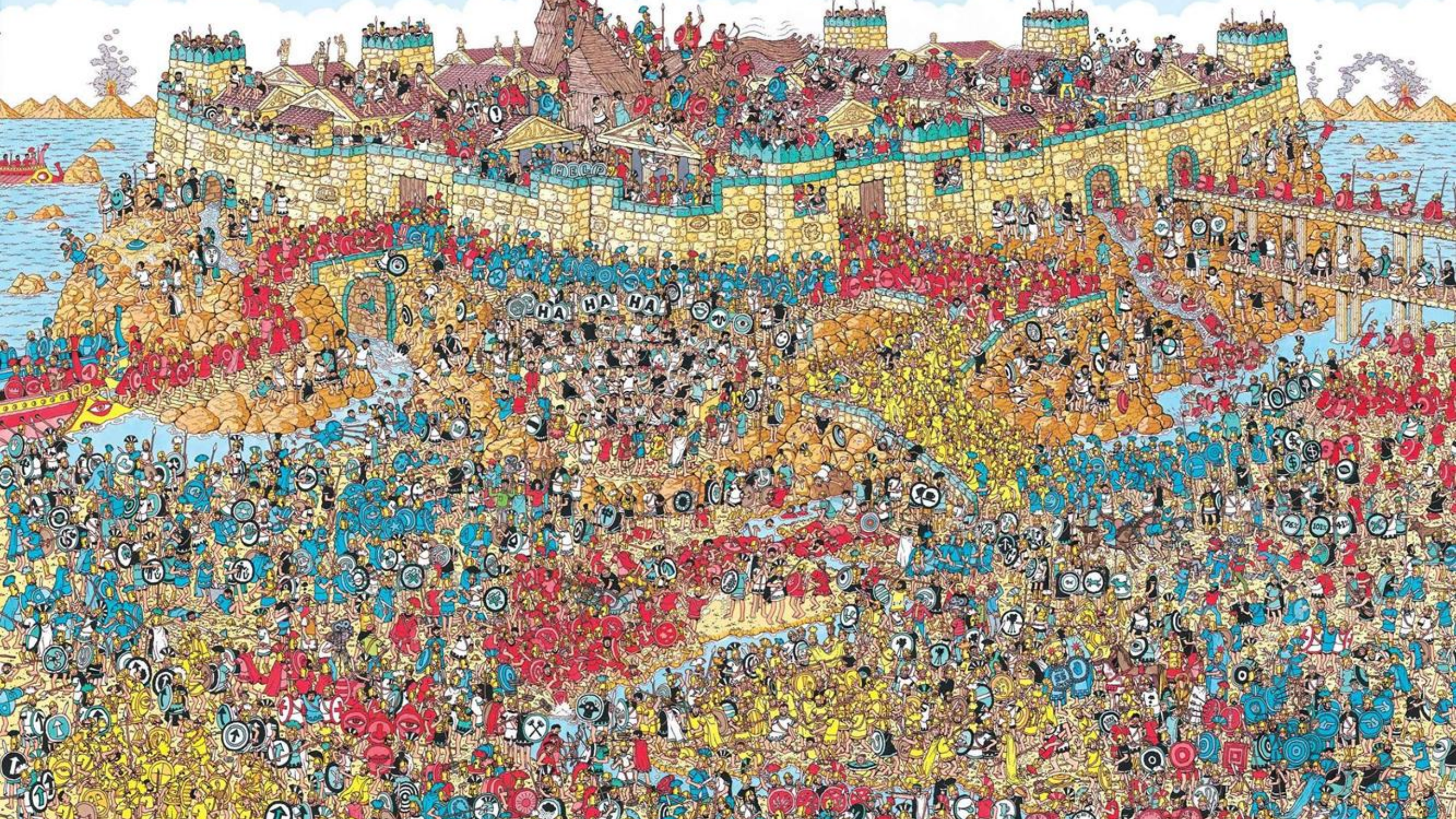
~~Can~~ try to correlate information
Will



Concrete constraints that require work

- Adherence to accepted standards (IETF SD-JWT, ISO mDoc, …). These are less-that-optimal formats for ZKPs and lead to big proofs.
- Needs to work on consumer phones, whereas most ZKP schemes focus on verifier’s efficiency.
- Needs to satisfy the trust and liability constraints of a public infrastructure, complicated or inflexible setups are undesirable.
- Needs to satisfy a level of auditability and maintainability.

Are ZKPs enough ?

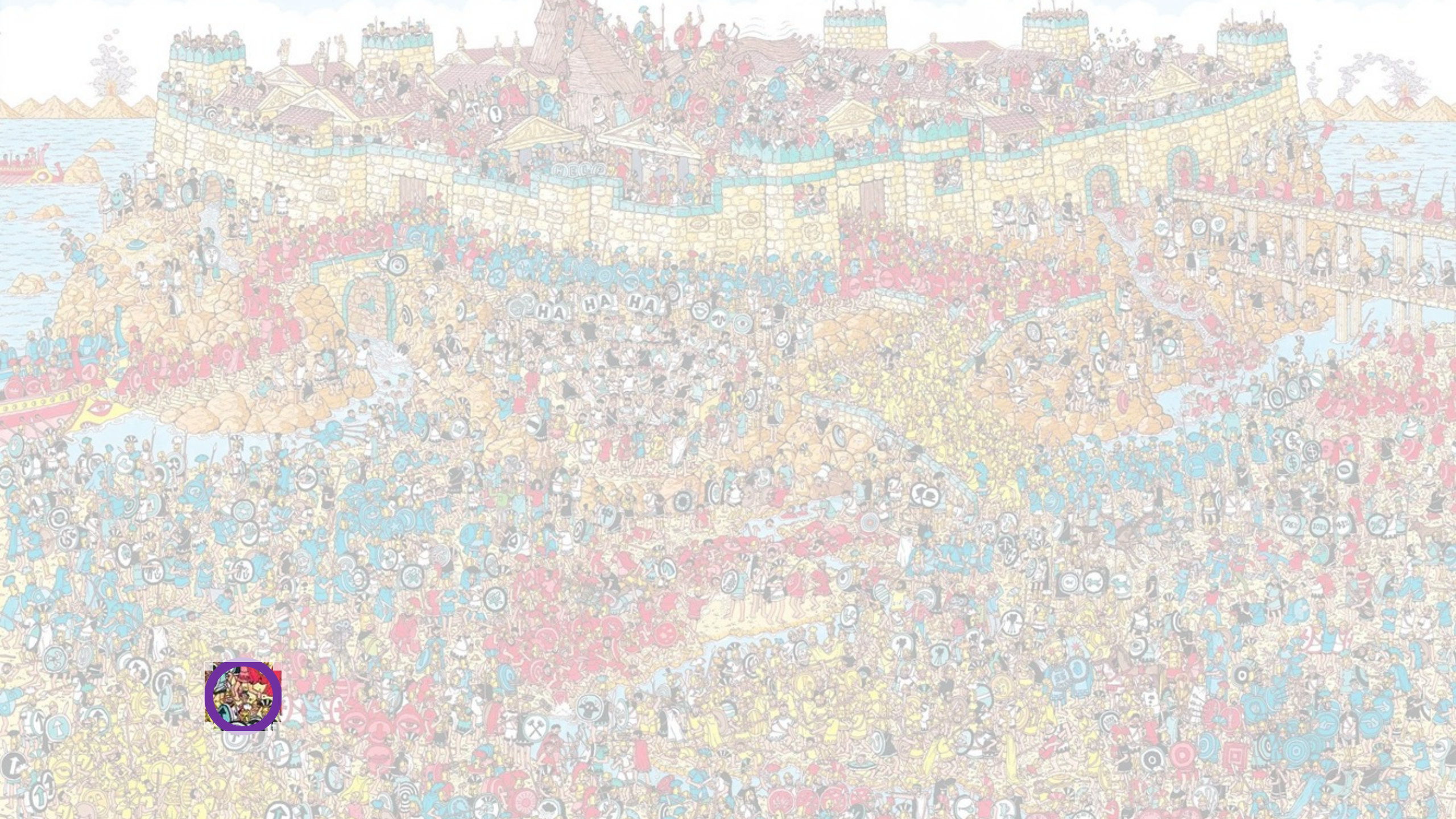

HA HA HA

Q&As

In which we do the exact opposite of ZKPs

References

- All the abstract examples: https://en.wikipedia.org/wiki/Zero-knowledge_proo
- Best blog on the internet about e-ID and ZKPs: https://eid-privacy.github.io
- Linus' treasure cave of ZKP papers: https://eid-privacy.github.io/zkp-vault/#resources-index
- SD-JWT for developers: https://github.com/chumbert/sd-jwt-crash-course
- Swiyu (Swiss e-ID): https://www.eid.admin.ch/en/swiyu-coming-soon-e


HA HA HA