# Interview presentation

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# ZK-SNARKs, what?

*Zero-Knowledge Succinct Non-interactive ARgument of Knowledge*:

- A multidisciplinary topic: math, complexity, cryptography[1].
- Prover wants to prove a statement, might be dishonest!
- Verifier wants to verify the proof, might be curious!
- Prover does not want to disclose secrets: **Zero-Knowledge**.
- Verifier does not want to waste time: **Succinct** proof.
- Prover proves once and for all: **Non-interactive**.
- Parties are "not too powerful": **ARgument of Knowledge**.

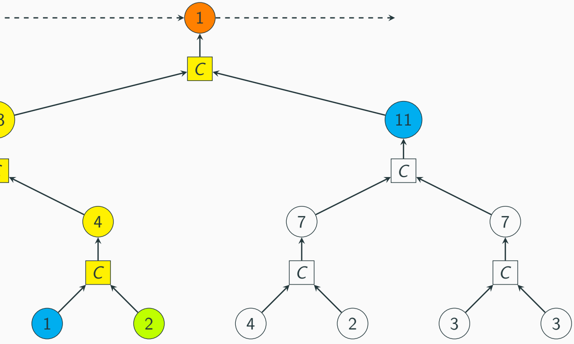
[1] A few milestones: [GMR89, Sha92, Dam93, Mic00, GGPR12, Gro16].

# ZK-SNARKs, why?

Many useful applications! For example:

- Cloud computing [PGHR13].
- Households figuring out their bills privately.
- **Anonymous transactions on the blockchain** [BSCG+14].

# The Blockchain

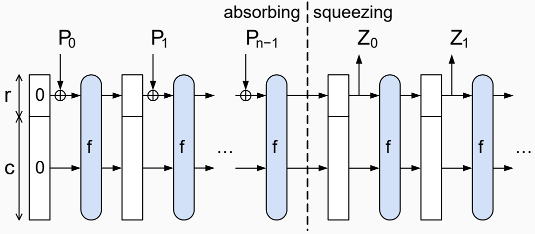



- Groups of transactions are leaves of a *Merkle tree* [Mer88].
- Bottom-up computation using a **compression function**.
- The root contains the *commitment* (among other data).
- Verify a commitment following the *authentication path*.

# Compression functions

One-way compression functions (OWCF):

- Many (e.g. 2) inputs and few (e.g. 1) outputs.
- Easy to compute, but hard to invert (and find collisions).
- Usually derived from one-way permutations.
- Standard designs (SHA [Dan15]) work over *boolean fields*.
- Davies-Meyer [Pre05], sponge [BDPVA07]...



# ZK-SNARK and compression functions

SHA is very fast natively, but what about in ZK-SNARK?

- Efficient ZK-SNARKs over prime fields $\mathbb{F}_p$ [GGPR12].
- Input-output relationship as bi-linear constraints (R1CS) [BSCTV13].
- One multiplication $=$ one constraint.
- What about SHA-256? 25000+ constraints!
- Can we do better?

# MiMC

Minimal Multiplicative Complexity (MiMC) hash function [AGR$^+$16]:

- Extremely simple: *round function* is $x^3 + c^2$.
- Many rounds to be secure against *algebraic attacks*.
- MiMCHash-256: 640 constraints.
- Can we do better?

[2]Warning: might not be a permutation!

Many improvements in the last years, POSEIDON [GKR$^+$21][3]:

- Partial *substitution-permutation network* (SPN) rounds.
- Full SPN for classic attacks (linear, differential. . . ).
- Partial SPN for algebraic attacks (interpolation, Gröbner. . . ).
- POSEIDON-256: 276 constraints.
- Can we do better?

[3] See also: [GHR$^+$22, BBC$^+$22, AABS$^+$19].

# Arion

Our design Arion [RST23]:

- Builds on the GTDS algebraic framework [RS22].
- Two variants: Arion and $\alpha$-Arion.
- $\alpha$-ArionHash-256: 76 constraints.

# Comparisons

`libsnark`: used by ZCash [BSCG+14] for its blockchain.

We used it to implement:

- Several primitives designed for ZK-SNARK, including ours.
- A self-parametrizing Merkle tree.
- A new mode of hash, the Augmented Binary tRee [ABR21].

Proof generation times for MT commitments over 256-bit prime fields

| Tree height | $\alpha$-ArionHash | Griffin | Poseidon |
|---|---|---|---|
| 4 | 73 ms | 88 ms | 186 ms |
| 8 | 145 ms | 181 ms | 386 ms |
| 16 | 278 ms | 338 ms | 745 ms |
| 32 | 509 ms | 622 ms | 1422 ms |

# $\mathcal{T}$he $\mathcal{E}$nd

*Thank you for your attention!*

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