Counting with STAR

Shipping A Privacy-Preserving Telemetry System To Millions Of Users

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USENIX PEPR '23

What is STAR?

1. **S**ecret Sharing for Private **T**hreshold **A**ggregation **R**eporting [CCS ‘22]

What is STAR?

1. **S**ecret Sharing for Private **T**hreshold **A**ggregation **R**eporting [CCS ‘22]
2. “Balls of gas burning billions of miles away”

STAR life-cycle

1. **Nebula**: why STAR
2. **Protostar**: designing STAR
3. **Red giant**: shipping & scaling
4. **Going supernova**: new features unlocked!
5. **Black holes**: and how to avoid them

Nebula.

a STAR is born

All Your Back to School Needs

walmart.com

Update

Walmart

Departments

Services

Search everything at Walmart online and in store

Reorder
My Items

Sign In
Account

$0.00

How do you want your items?

San Francisco, 94117

San Leandro Store

Deals | Grocery & Essentials | Back to School | Top Toys List | Beauty Glow Up | Fashion | Home | Electronics | Registry

Save on auto, from $78

Shop now

See ya, summer!

Labor Day savings

Shop now

Mattresses for less from $65

Shop now

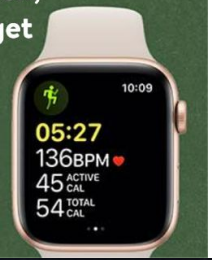
Top savings from Bissell

Shop now

Was $195

The best tech, under budget

Shop now



From

Up to 65% off

Shop now

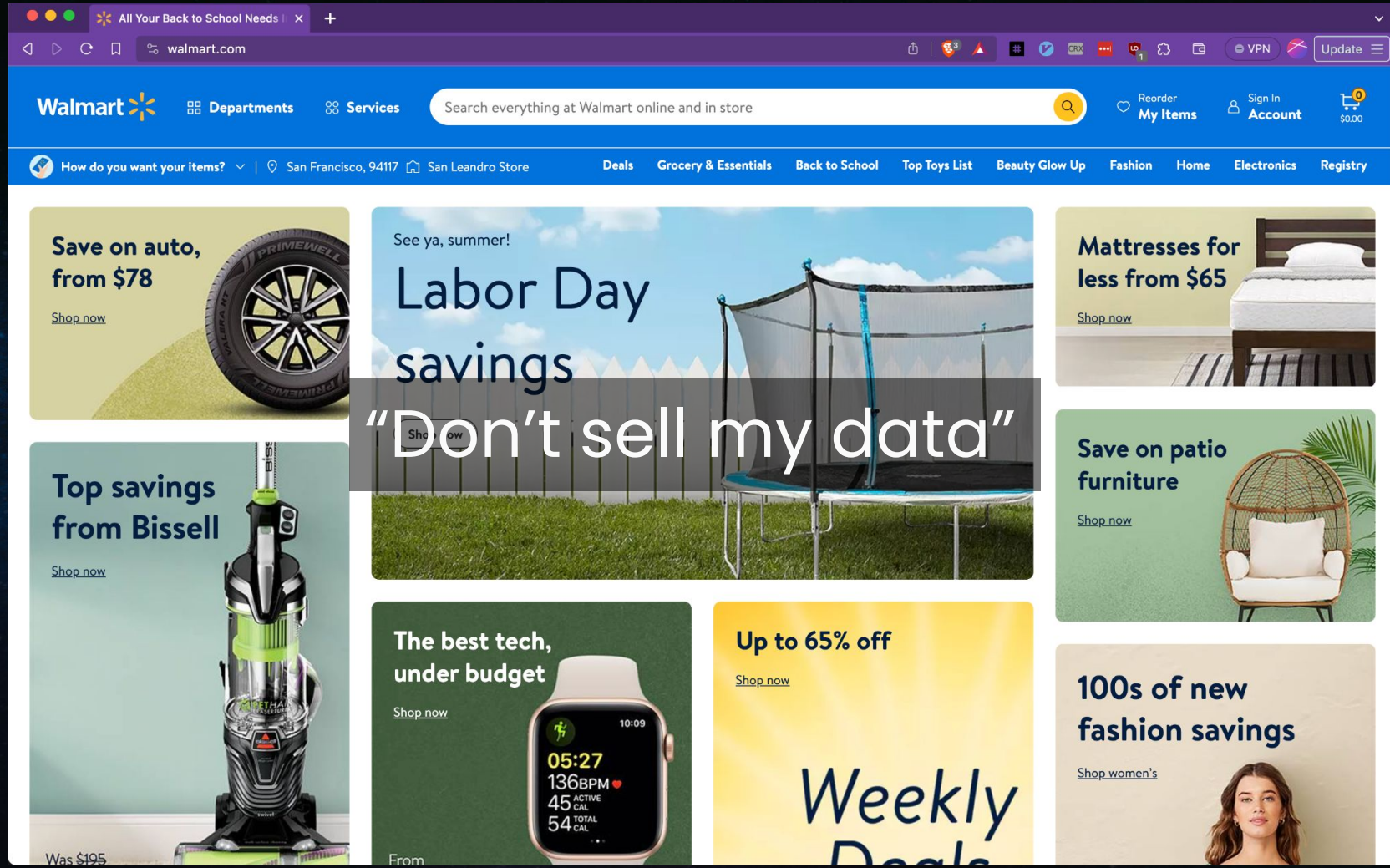
Weekly

Save on patio furniture

Shop now

100s of new fashion savings

Shop women's


All Your Back to School Needs
walmart.com
VPN
Update
Walmart
Departments
Services
Search everything at Walmart online and in store
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$0.00
How do you want your items?
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“Don’t sell my data”

Login

walmart.com/account/login?vid=oaoh&tid=0&returnUrl=%2F

VPN Update

Sign in or create your account

Not sure if you have an account?
Enter your email and we'll check for you.

Email Address

Continue

Securing your personal information is our priority.
See our privacy measures.

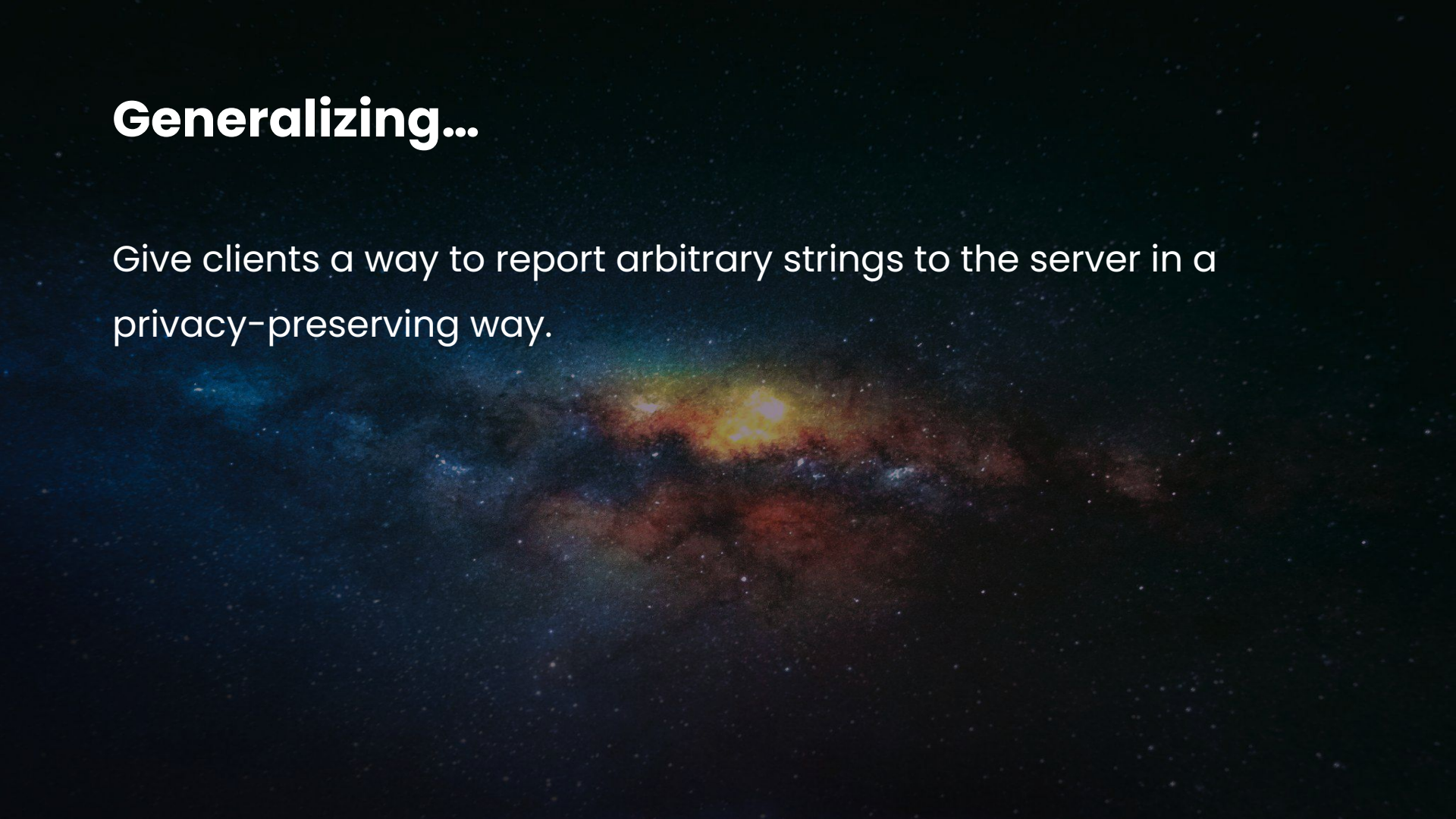
Give feedback | CA Privacy Rights | Your Privacy Choices | Notice at Collection | Request My Personal Information | California Supply Chains Act

Give users a way to report **https://walmart.com** as broken

Give users a way to report **https://walmart.com** as broken with some amount of privacy cover

Generalizing...

Give clients a way to report arbitrary strings to the server in a privacy-preserving way.



Options

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    a. Too slow and/or expensive
    b. Complicated to deploy
    c. Bad failure mode under collusion

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Takeaway: simplicity is important for user trust

Options

1. MPC-based (Prio, Poplar)
2. Differential privacy-based (RAPPOR, IPA)
    a. (central) not user-auditable
    b. Hard to test
    c. (central) Bad failure mode
    d. (local) Requires large user base
    e. Hard to use for exact strings

Options

1. MPC-based (Prio, Poplar)
2. Differential privacy-based (RAPPOR, IPA)

Takeaway: once data leaves device, all bets are off

Generalizing...

Give clients a way to report arbitrary strings to the server only if N other users also reported that string.

STAR goals

Cheap

Simple

Private

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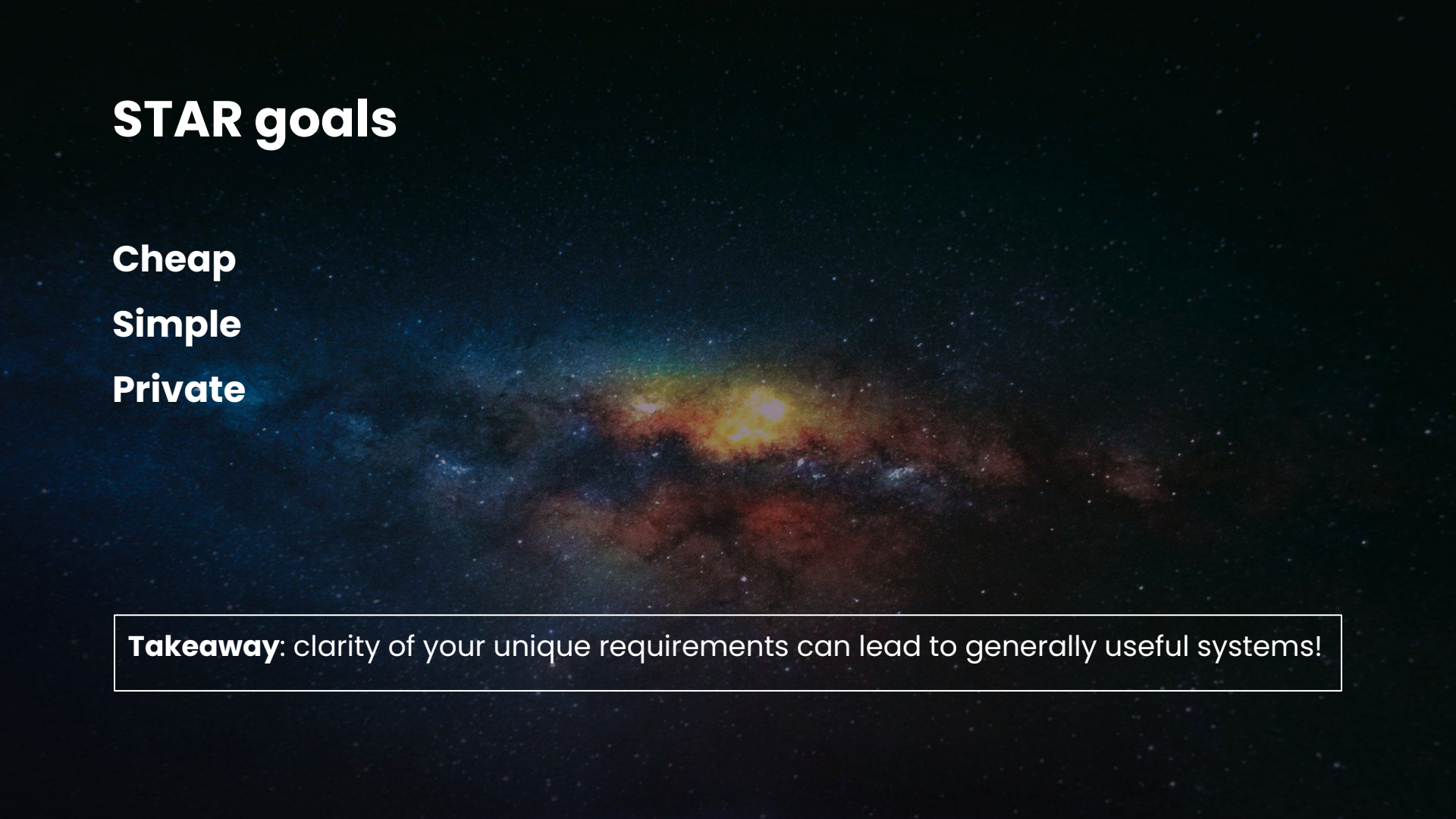


Takeaway: clarity of your unique requirements can lead to generally useful systems!

Protostar.

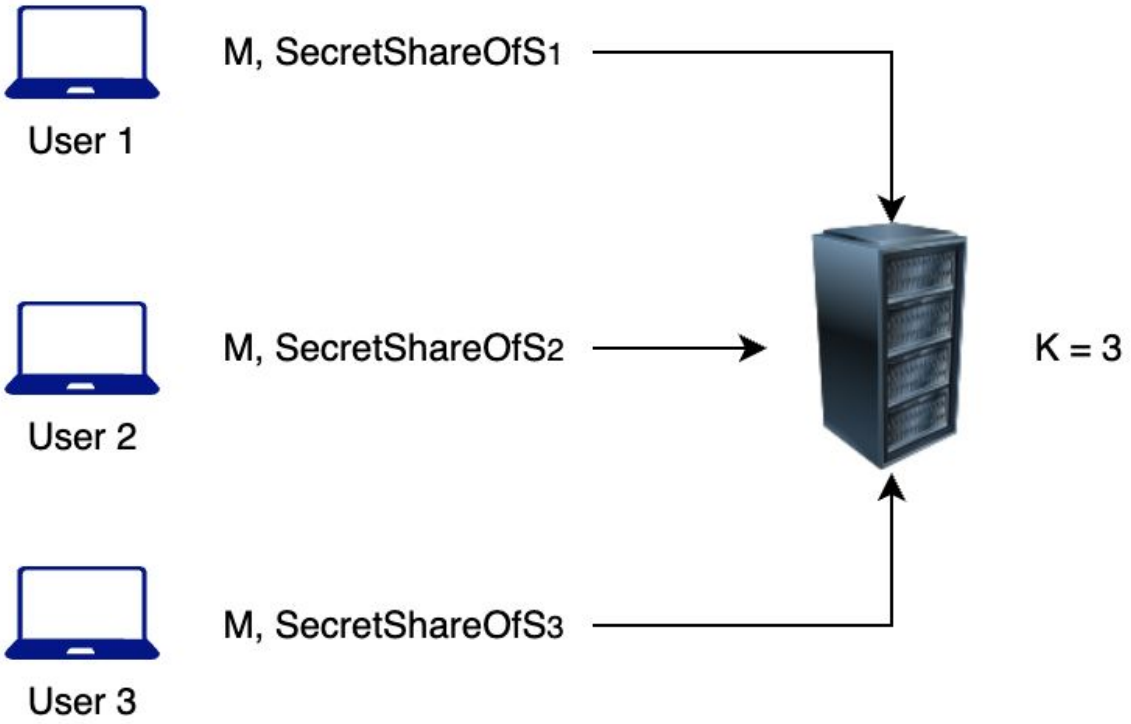
design

STAR

1. K-threshold aggregation scheme
2. Secret sharing
3. OPRFs (oblivious pseudorandom functions) to derive randomness for low entropy input space

Client wants to send “walmart.com”

1. Hash “walmart.com” to get random value=> **R**
2. Derive symmetric key **S** from **R** = **derive**(R)
3. Encrypts message “walmart.com” using **S**: **M** = **Encrypt**(S, “walmart.com”)
4. Generate secret share of **S**: **SecretShareOfS**$_i$
5. Client sends server: {**M, SecretShareOfS**$_i$**}**


User 1
M, SecretShareOfS1
User 2
M, SecretShareOfS2
User 3
M, SecretShareOfS3
K = 3

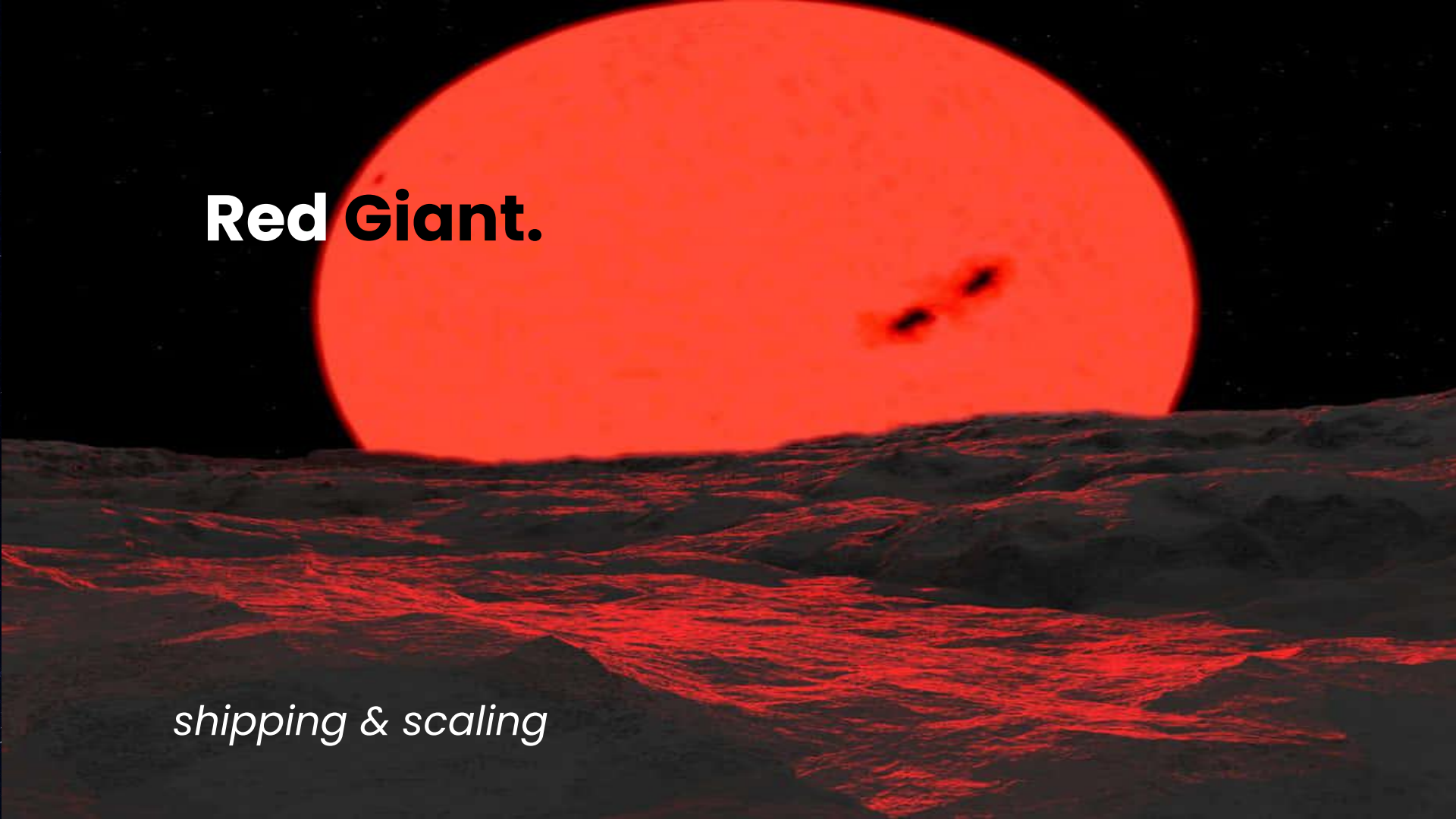
Server can decrypt after it has K shares

1. Recover encryption key: **S** = **Recover**(SecretShareOfS$_{i..K}$)
2. Use S to decrypt **M**:

   “walmart.com” = **Decrypt**(S, M)

STAR goals

1. **Cheap**
    a. 24x cheaper than alternatives [1]
2. **Simple**
    a. Straightforward protocol
    b. One server model (when randomness derived locally)
3. **Private**
    a. K value is verifiable by clients


Red Giant.
shipping & scaling

Shipping & Scaling

1. Evolved the protocol
2. Many, many prototypes
3. Academia (PPORPF) + standards (verifiability)
4. First deployment was specifically for one use-case (JS)
5. Expanded out to more general C++ browser support
6. Went through security & privacy review
7. Open-sourced
8. Whole process took a year

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Takeaway: boring crypto is good!

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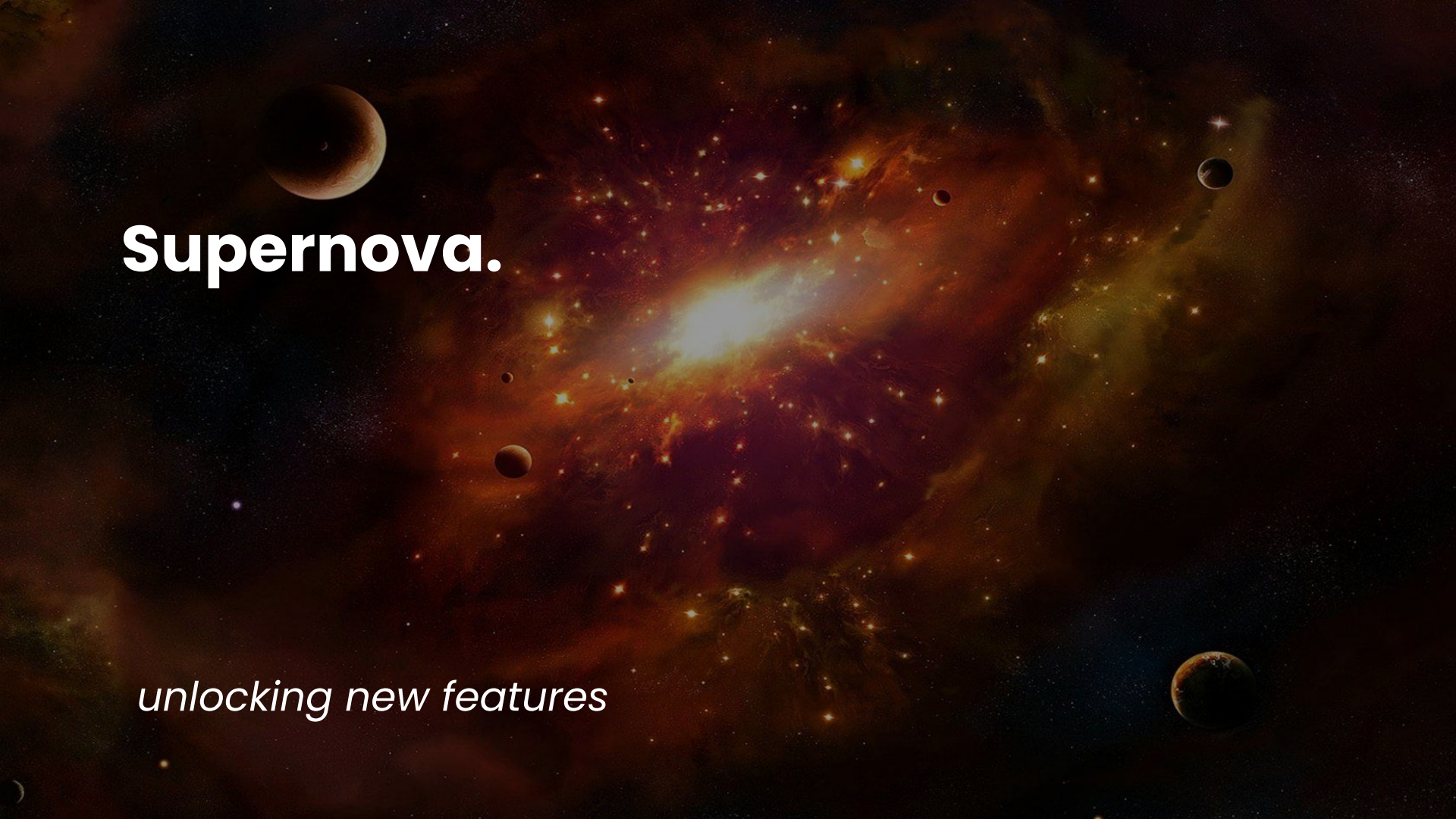
Takeaway: academic/standards process can improves your system


Supernova.
unlocking new features

New features

1. Web Discovery Project
2. Ref codes

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2. Ref codes

Takeaway: telemetry systems are surprisingly useful for many things!

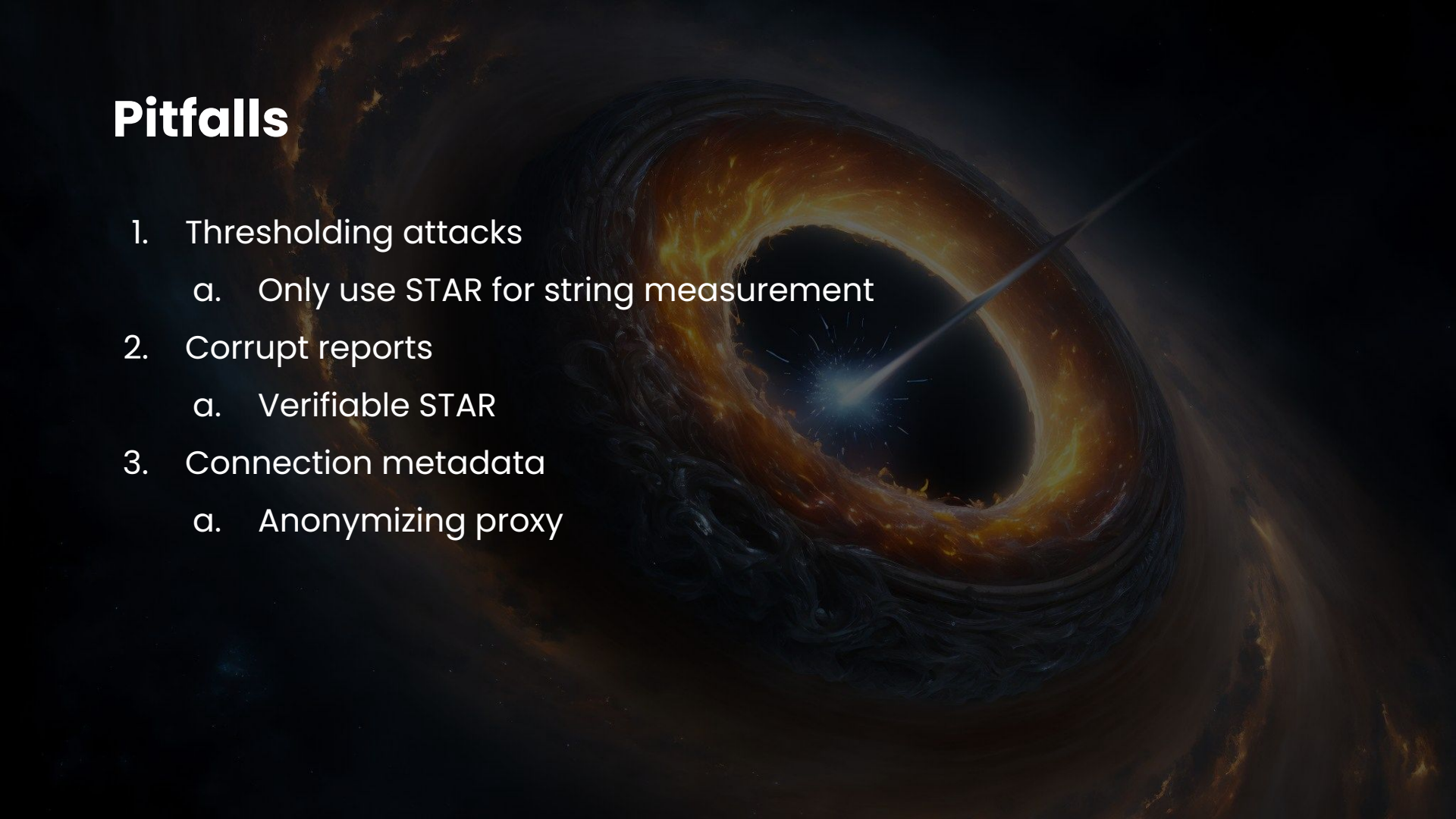
New features

1. Web Discovery Project
2. Ref codes
3. Country codes? No!


Black holes.
pitfalls

Pitfalls

1. Thresholding attacks
    a. Only use STAR for string measurement
2. Corrupt reports
    a. Verifiable STAR
3. Connection metadata
    a. Anonymizing proxy



Takeaways & goodbyes

1. Simplicity is important for user trust
2. Once data leaves device, all bets are off
3. Clarity of your unique requirements can lead to generally useful systems!
4. Boring crypto is good!
5. Academic/standards process can improves your system
6. Telemetry systems are surprisingly useful for many things!

Links: research paper, blog post, IETF draft

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SUPER STAR

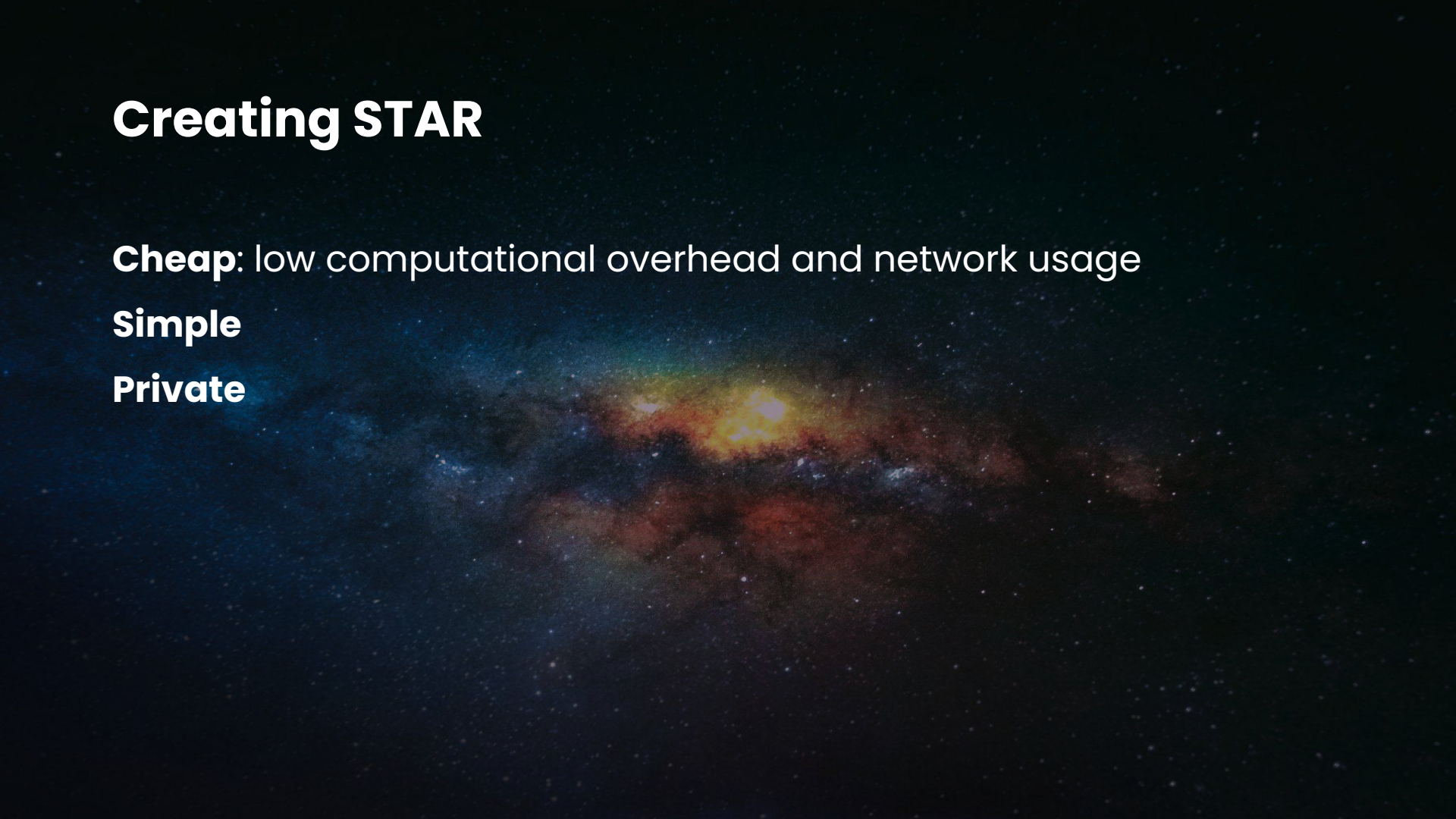
Secret Sharing Scheme	**Signature Scheme/Protocol**	**Client threat mitigated**
Shamir Secret Sharing	OPRF	None
Verifiable Secret Sharing	OPRF	Bad shares (DoS)
Shamir Secret Sharing	Blind Signatures	Bad ciphertext
Verifiable Secret Sharing	Blind Signatures	Both

Creating STAR

Cheap: low computational overhead and network usage

Simple

Private



Creating STAR

Cheap: low computational overhead and network usage

Simple: easy to implement, well-known crypto

Private

Creating STAR

Cheap: low computational overhead and network usage

Simple: easy to implement, well-known crypto

Private: practical privacy guarantees for clients