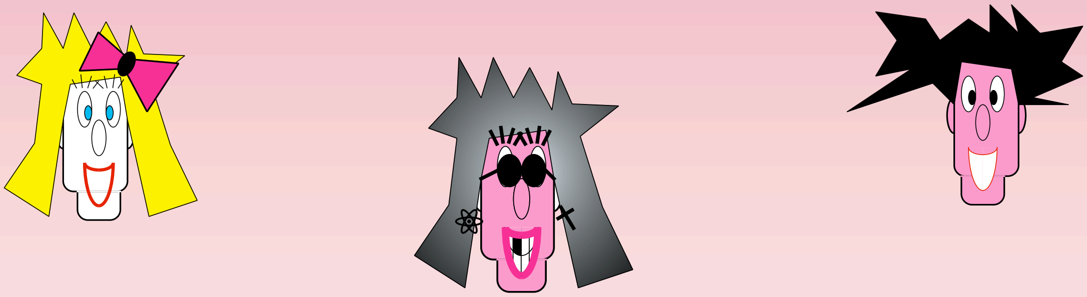
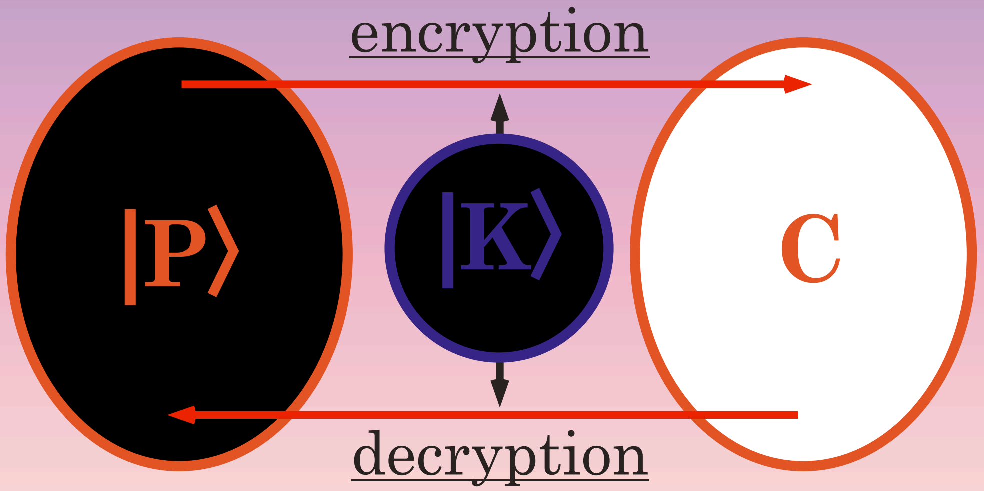
(3.1.2) One-time pad

Classical key : Vernam Q-cipher (various sources)
Quantum Ciphertext

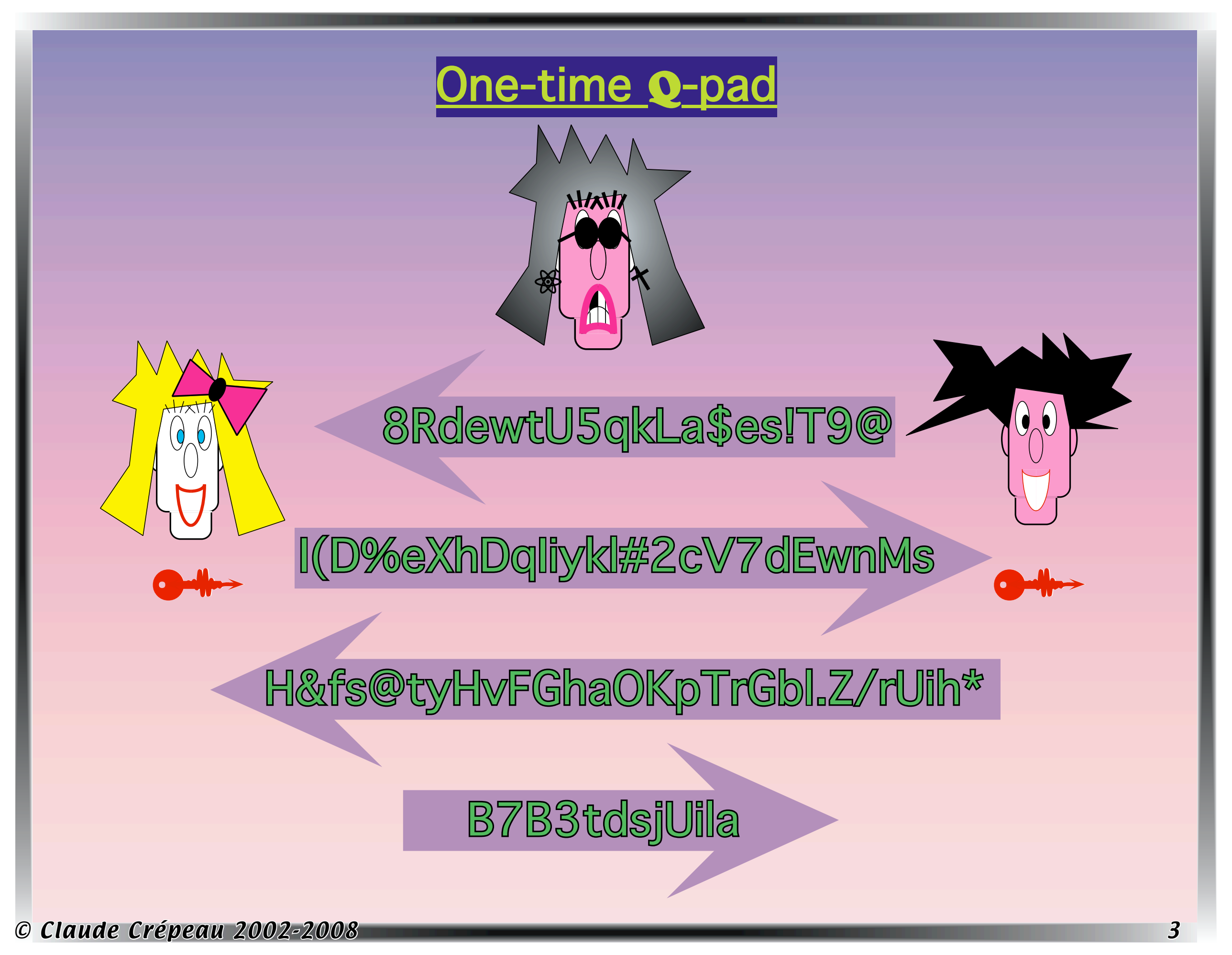
Quantum key : one-time Q-pad (Q-teleportation)
Classical Ciphertext (BBCJPW)



symmetric encryption of Quantum messages



Information Theoretical Security



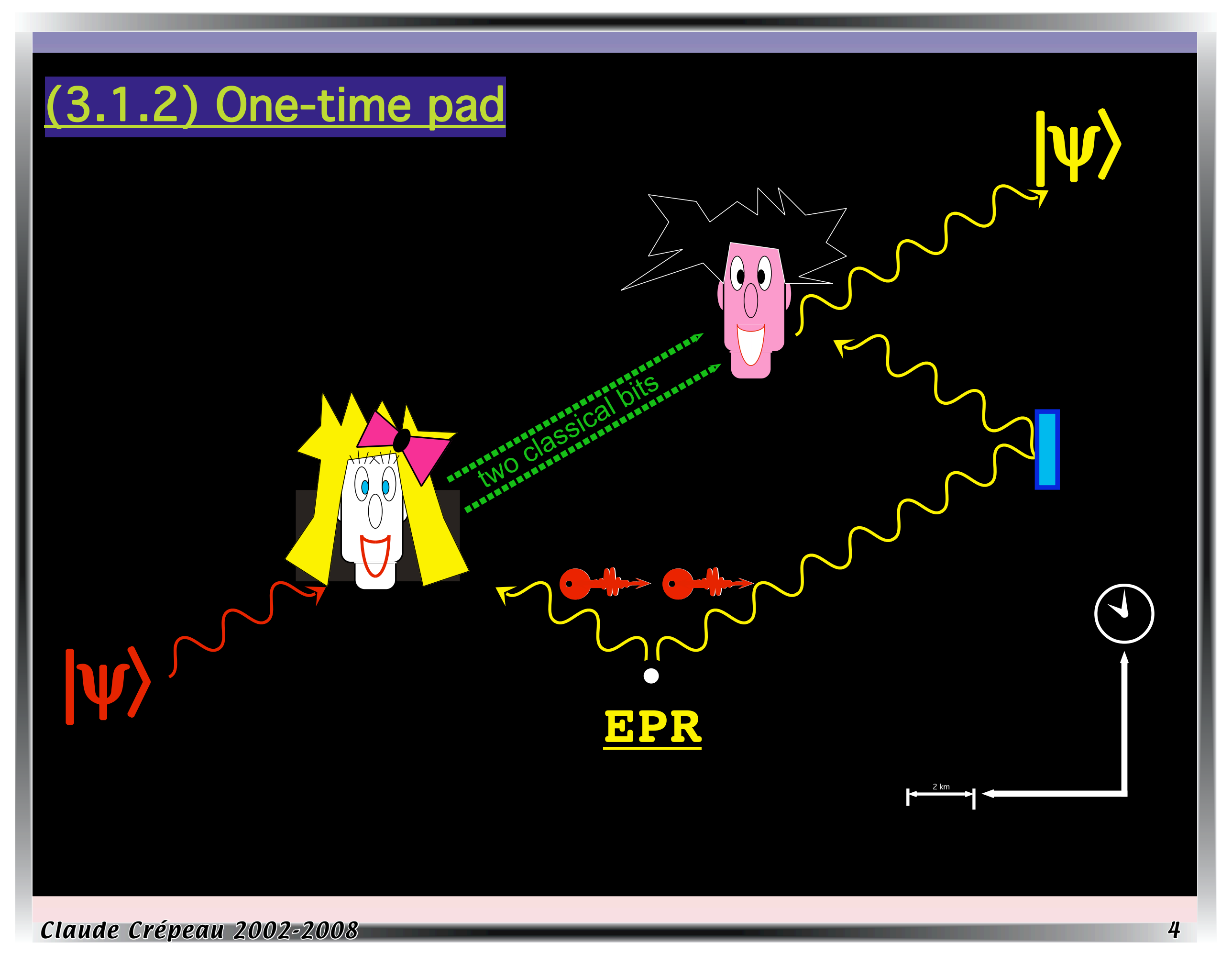
One-time Q-pad

8RdewtU5qkLa$es!T9@

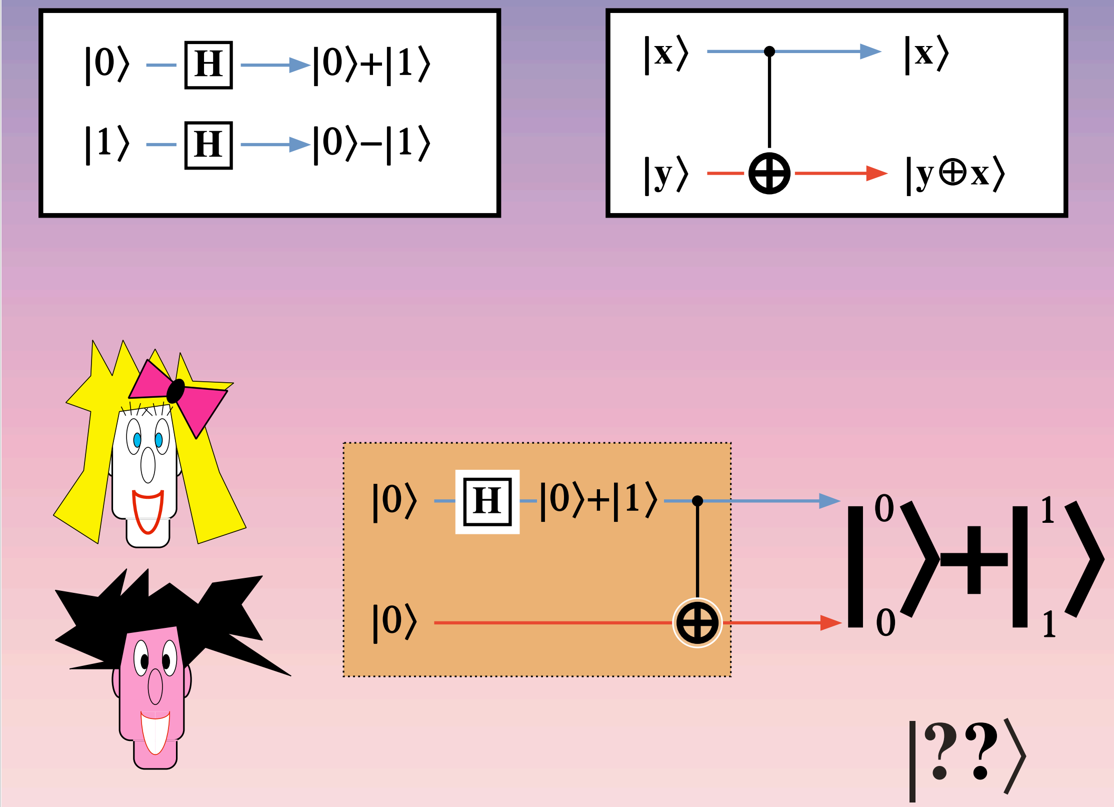
I(D%eXhDqliykl#2cV7dEwnMs

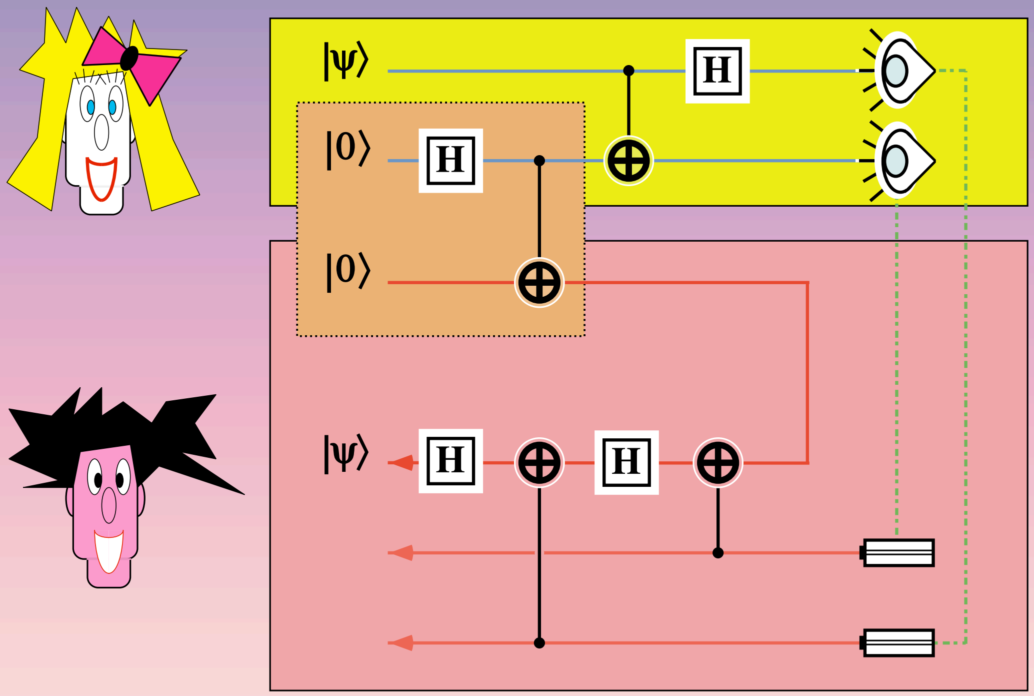
H&fs@tyHvFGhaOKpTrGbl.Z/rUih*

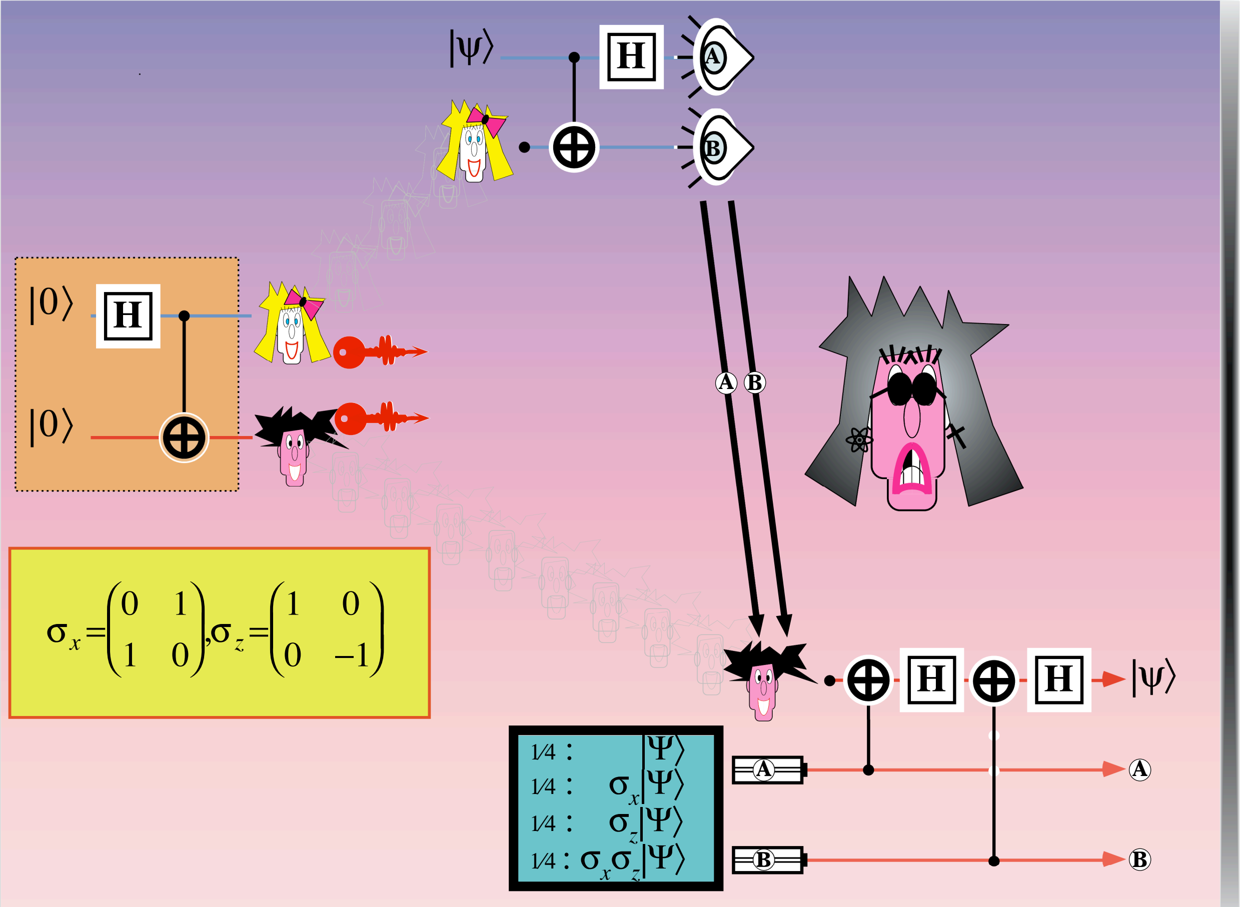
B7B3tdsjUila



(3.1.2) One-time pad


|0⟩ H |0⟩+|1⟩
|1⟩ H |0⟩−|1⟩
|x⟩ |x⟩
|y⟩ ⊕ |y⊕x⟩
|0⟩ H |0⟩+|1⟩
|0⟩ ⊕
|⁰₀⟩+|¹₁⟩
|??⟩


|ψ⟩
H
|0⟩
H
⊕
|0⟩
⊕
|ψ⟩
H
⊕
H
⊕



$$\sigma_x=\begin{pmatrix}0 & 1\\ 1 & 0\end{pmatrix},\sigma_z=\begin{pmatrix}1 & 0\\ 0 & -1\end{pmatrix}$$

1/4 : $|\Psi\rangle$
1/4 : $\sigma_x|\Psi\rangle$
1/4 : $\sigma_z|\Psi\rangle$
1/4 : $\sigma_x\sigma_z|\Psi\rangle$

(3.1.2b) one-time pad

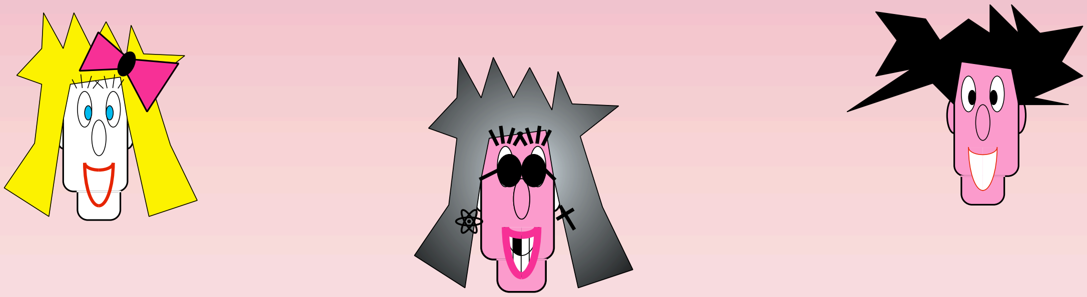
Quantum key : one-time Q-pad
Classical Ciphertext

two random bits
|Ψ⟩

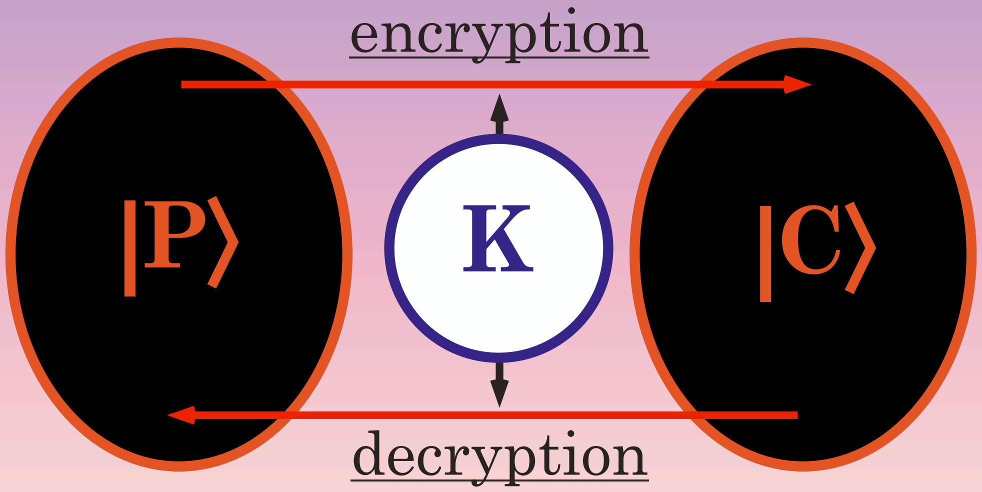
(3.1.2a) One-time pad

Classical key : Vernam Q-cipher (various sources)
Quantum Ciphertext

Quantum key : one-time Q-pad (BBCJPW)
Classical Ciphertext



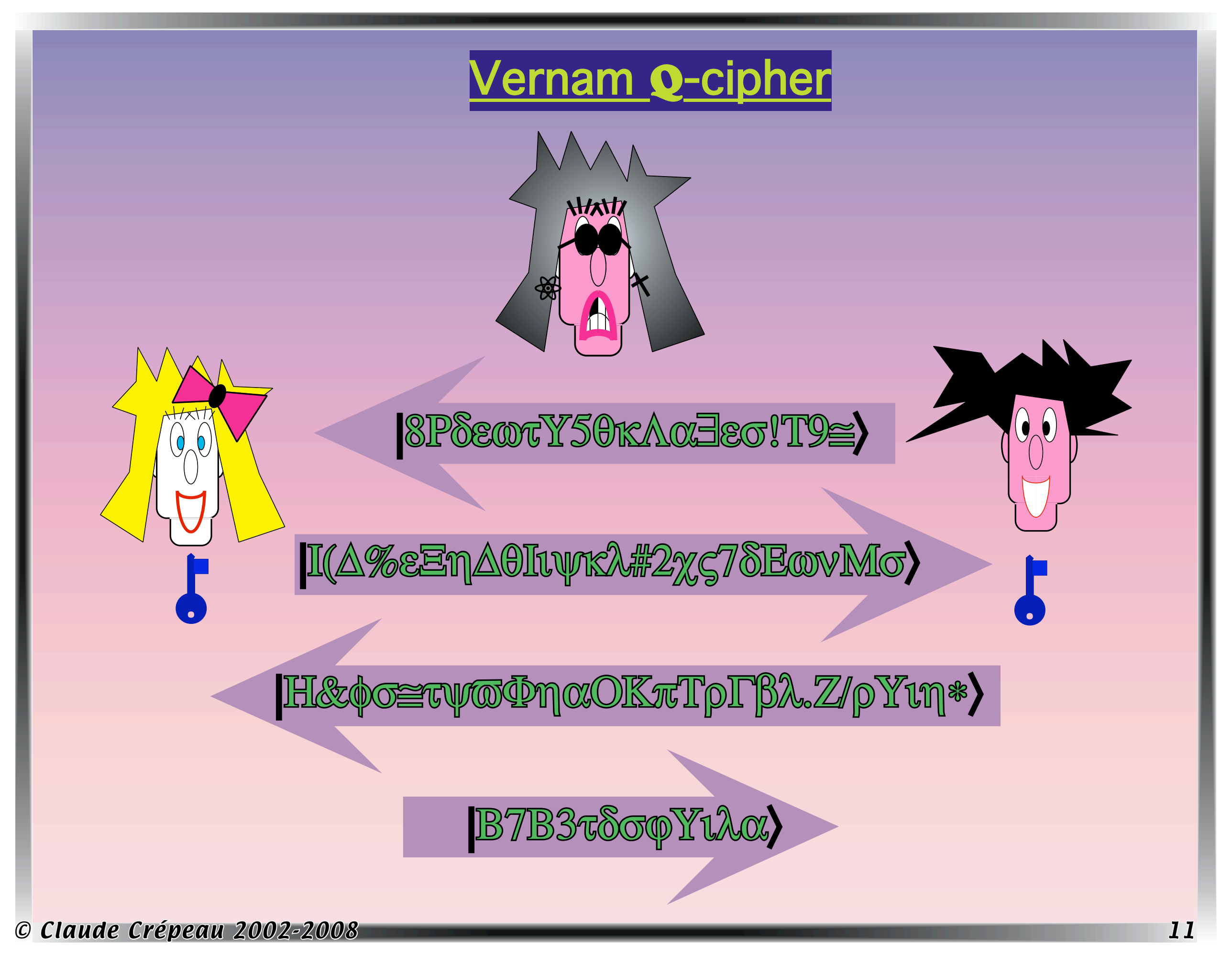
symmetric encryption of Quantum messages



encryption

decryption

Information Theoretical Security



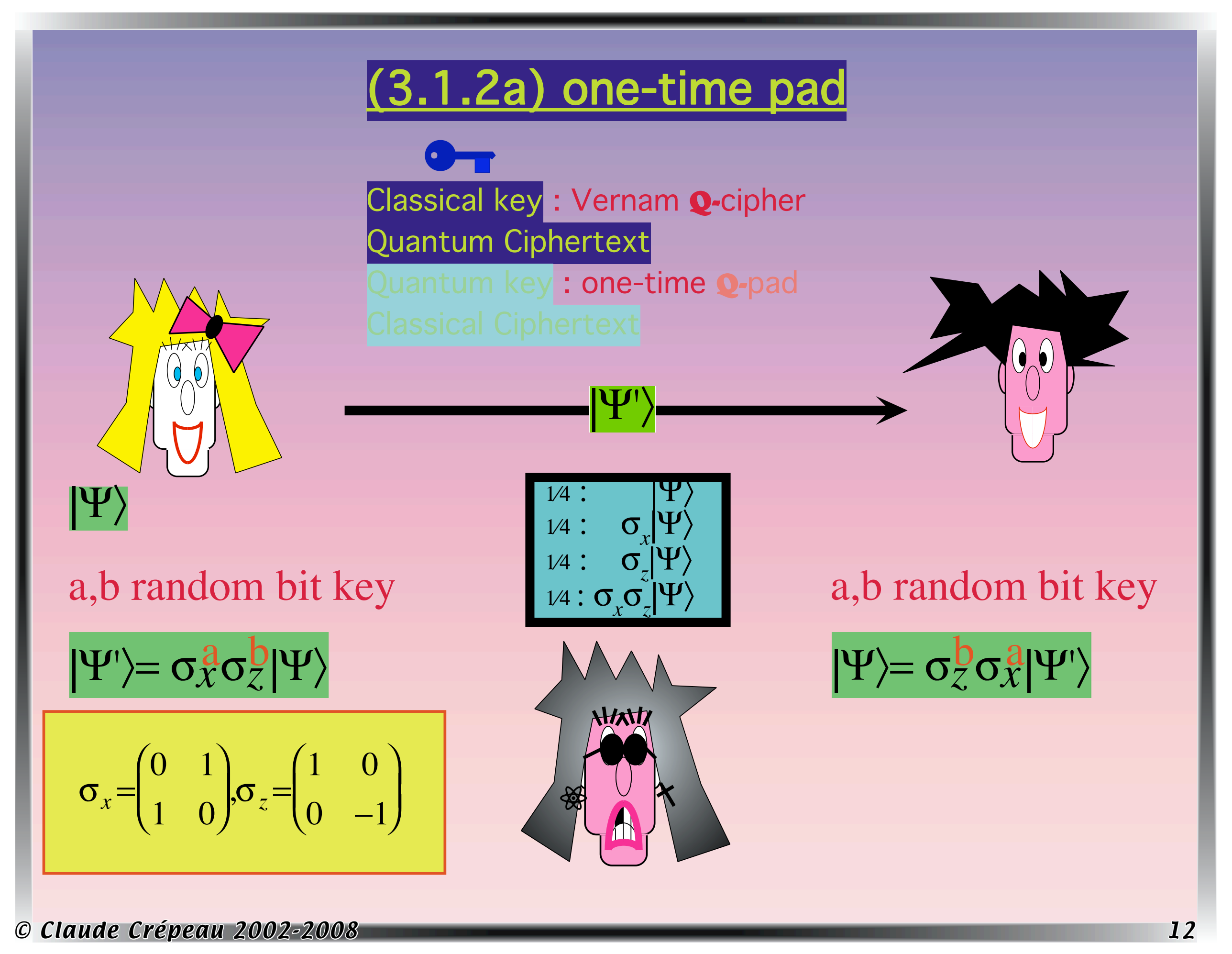
Vernam Q-cipher

|8PδεωτΥ5θκΛα∃εσ!Τ9≅⟩

|Ι(Δ%εΞηΔθΙιψκλ#2χς7δΕωνΜσ⟩

|Η&φσ≅τψϖΦηαΟΚπΤρΓβλ.Ζ/ρΥιη*⟩

|Β7Β3τδσφΥιλα⟩



(3.1.2a) one-time pad

Classical key : Vernam Q-cipher
Quantum Ciphertext
Quantum key : one-time Q-pad
Classical Ciphertext

$|\Psi'\rangle$

$|\Psi\rangle$

a,b random bit key

$|\Psi'\rangle = \sigma_x^a \sigma_z^b |\Psi\rangle$

$$\sigma_x = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \sigma_z = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

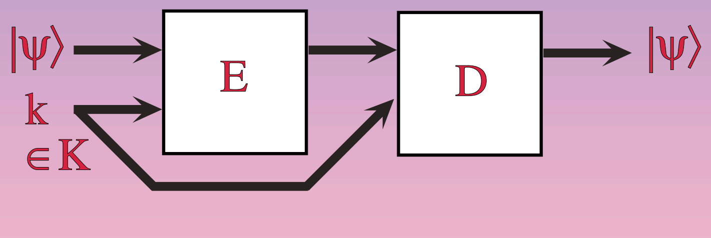
1⁄4 : $|\Psi\rangle$
1⁄4 : $\sigma_x|\Psi\rangle$
1⁄4 : $\sigma_z|\Psi\rangle$
1⁄4 : $\sigma_x\sigma_z|\Psi\rangle$

a,b random bit key

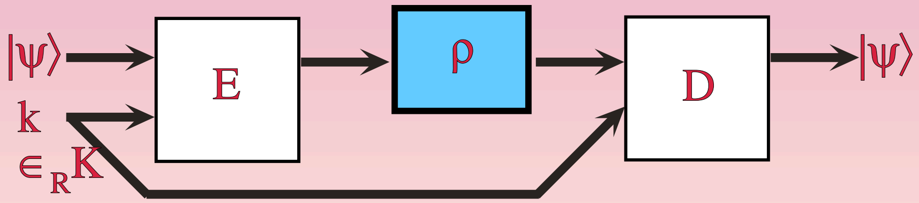
$|\Psi\rangle = \sigma_z^b \sigma_x^a |\Psi'\rangle$

One-time Q-encryption with error ε

Completeness:



Secrecy:



$$\boxed{\forall |\psi_0\rangle, |\psi_1\rangle \quad D(\rho_0,\rho_1)=\mathrm{Tr}(|\rho_0-\rho_1|)<\varepsilon}$$

One-time Q-encryption with error ε>0

Lower bounds:

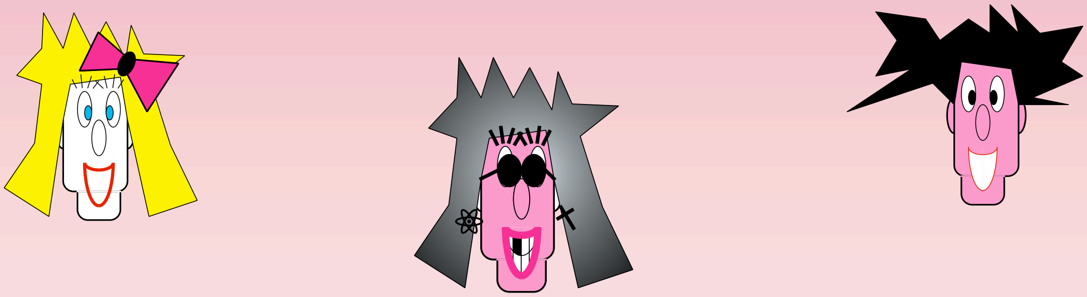
[MTW00]
Arbitrary quantum state = 2 bits / qubit

[HLSW03]
Arbitrary quantum state but not entangled with eavesdropper ~ 1 bit / qubit

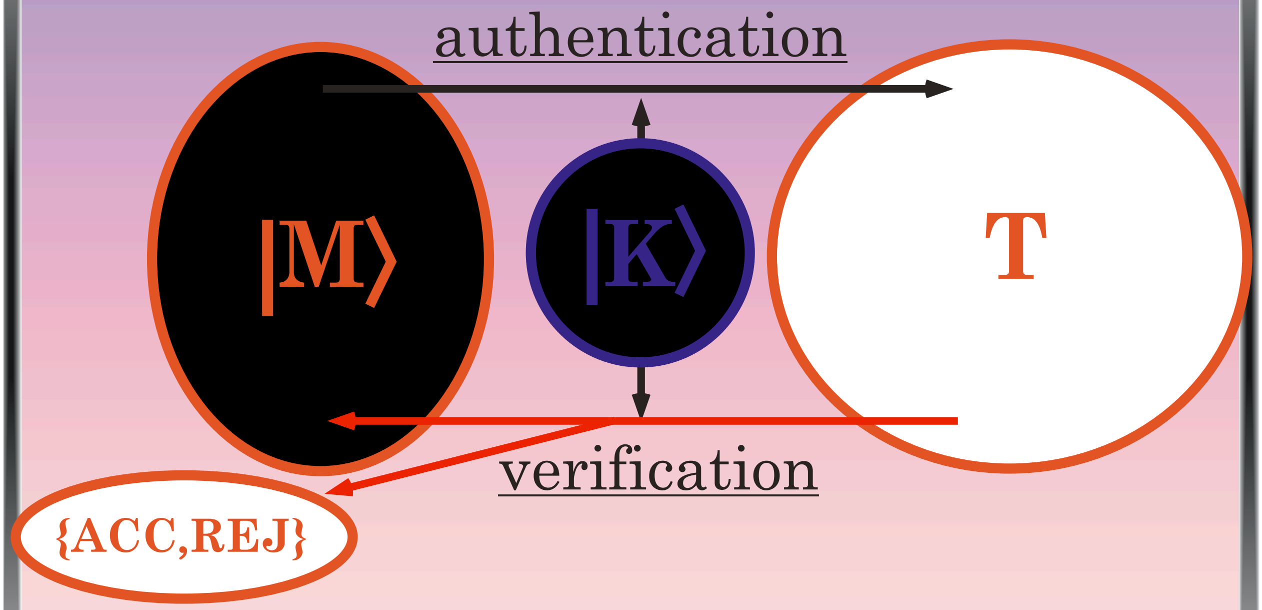
(3.1.3) One-time Q-Authentication

Classical key : Q-Authentication (BCGST)
Quantum message+tag

Quantum key : Authenticated Q-teleportation
Classical message+tag (BBCJPW)

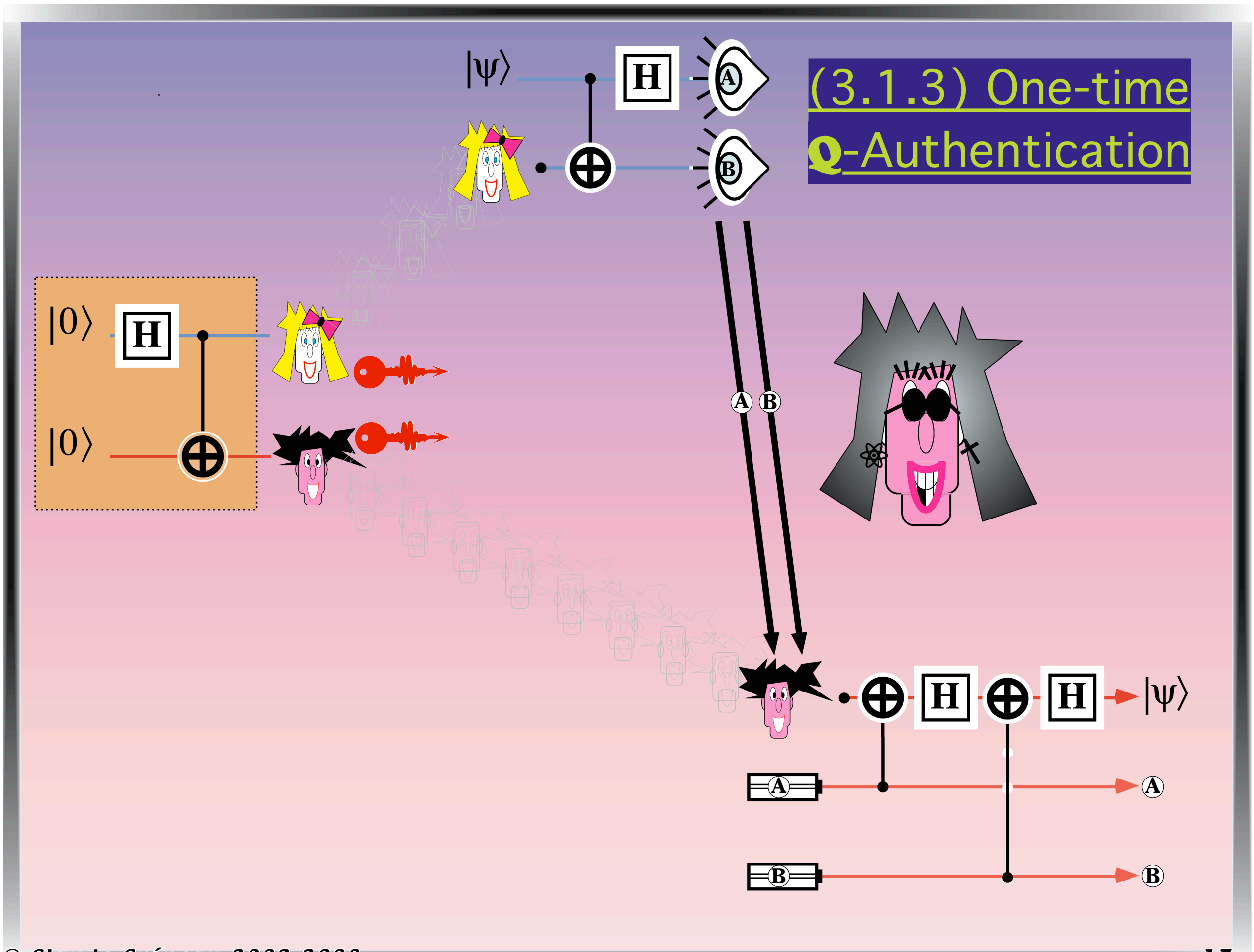


symmetric authentication

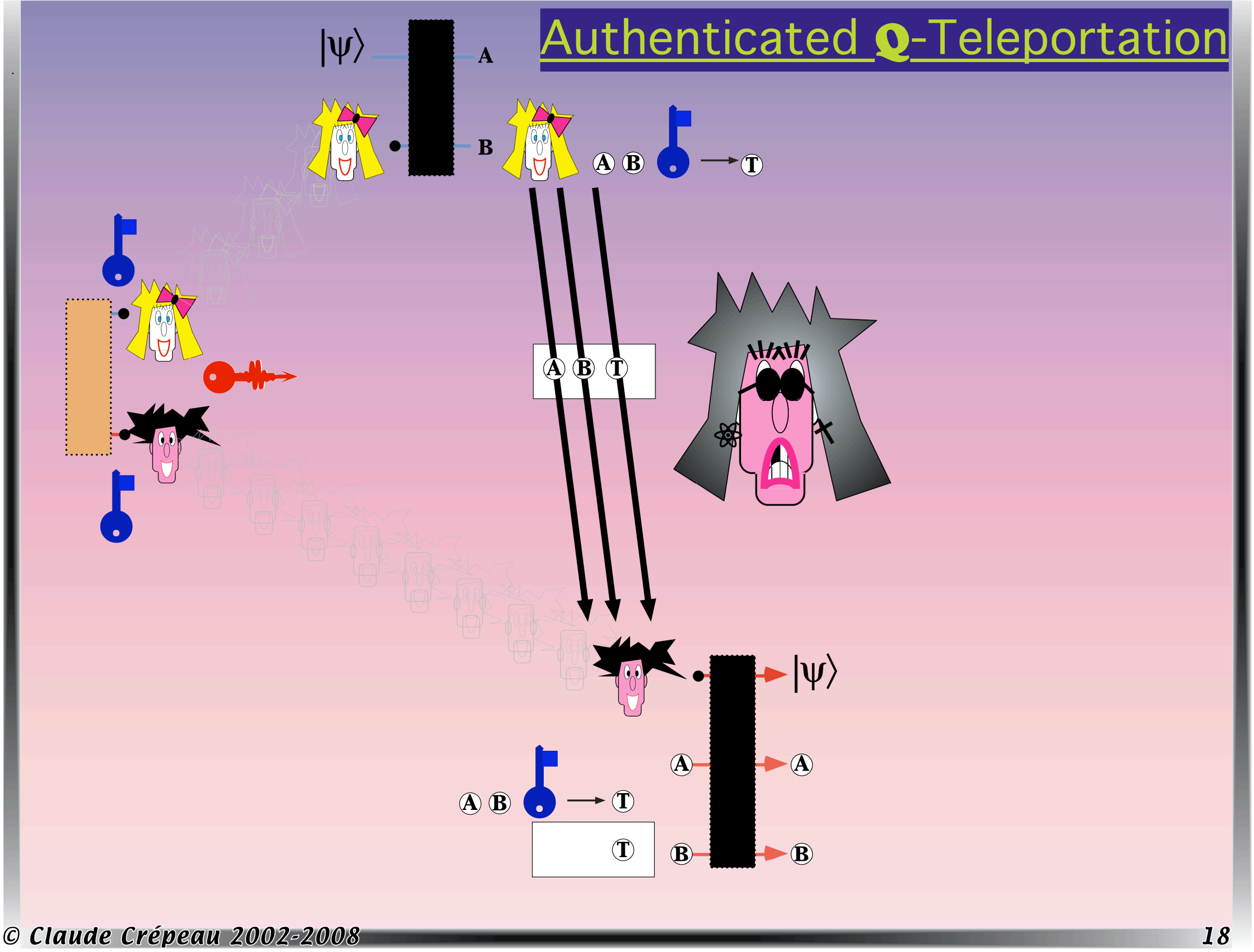


Information Theoretical Security

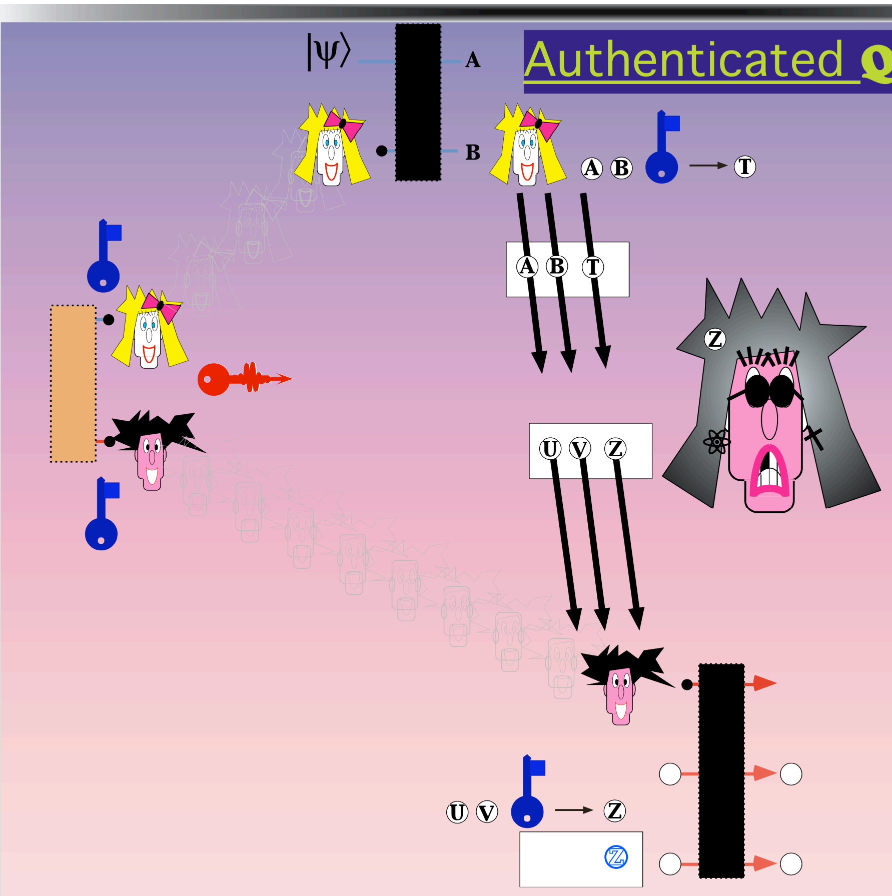
(3.1.3) One-time Q-Authentication



Authenticated Q-Teleportation



Authenticated Q-Teleportation



(3.1.3b) One-time Q-Authentication

Quantum key : 1x Authenticated Q-pad

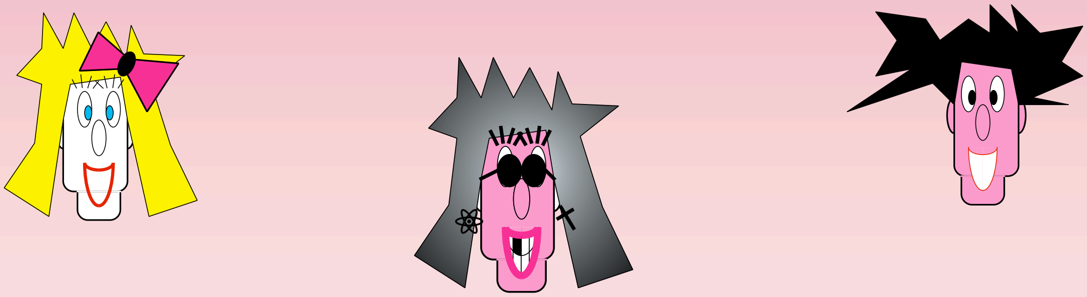
Classical message+tag

two authenticated random bits

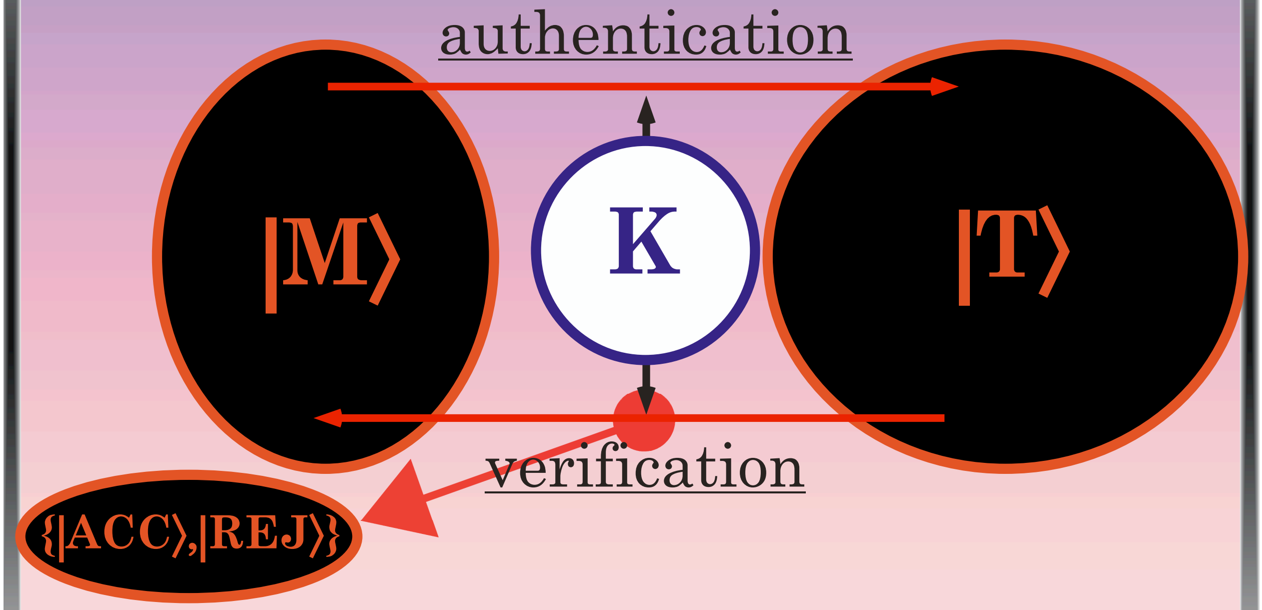
(3.1.3a) One-time Q-Authentication

Classical key : Q-Authentication (BCGST)
Quantum message+tag

Quantum key : Authenticated Q-teleportation
Classical message+tag (BBCJPW)

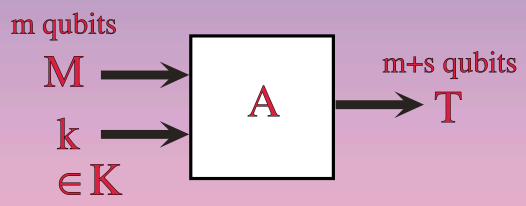


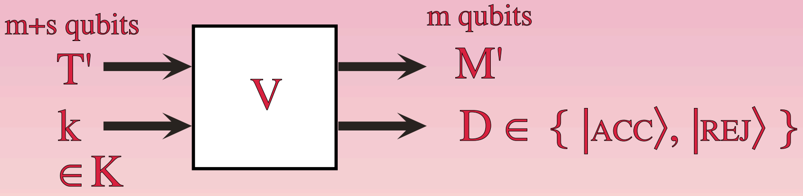
symmetric authentication of Quantum Messages



Information Theoretical Security

One-time Q-Authentication




m+s qubits
T'
k
∈K
V
m qubits
M'
$D \in \{\, |\textsc{acc}\rangle, |\textsc{rej}\rangle \,\}$

One-time Q-Authentication

For any pure state $|\psi\rangle$ consider the measurement on (M',D) such that

- output Right if $M'=|\psi\rangle$ or if $D=|\textsc{rej}\rangle$
- output Wrong otherwise

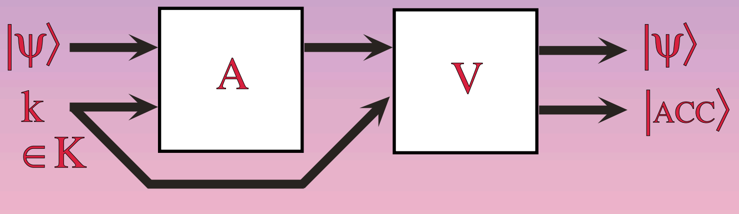
The corresponding projectors are

$$R_{|\psi\rangle} = |\psi\rangle\langle\psi| \otimes I_D + I_{M'} \otimes |\textsc{rej}\rangle\langle\textsc{rej}| - |\psi\rangle\langle\psi| \otimes |\textsc{rej}\rangle\langle\textsc{rej}|$$

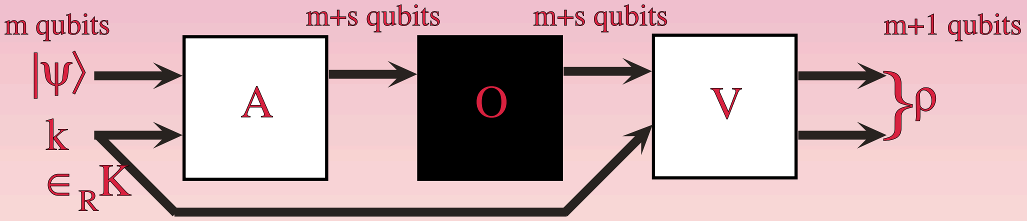
$$W_{|\psi\rangle} = (I_{M'} - |\psi\rangle\langle\psi|) \otimes |\textsc{acc}\rangle\langle\textsc{acc}|$$

One-time Q-Authentication

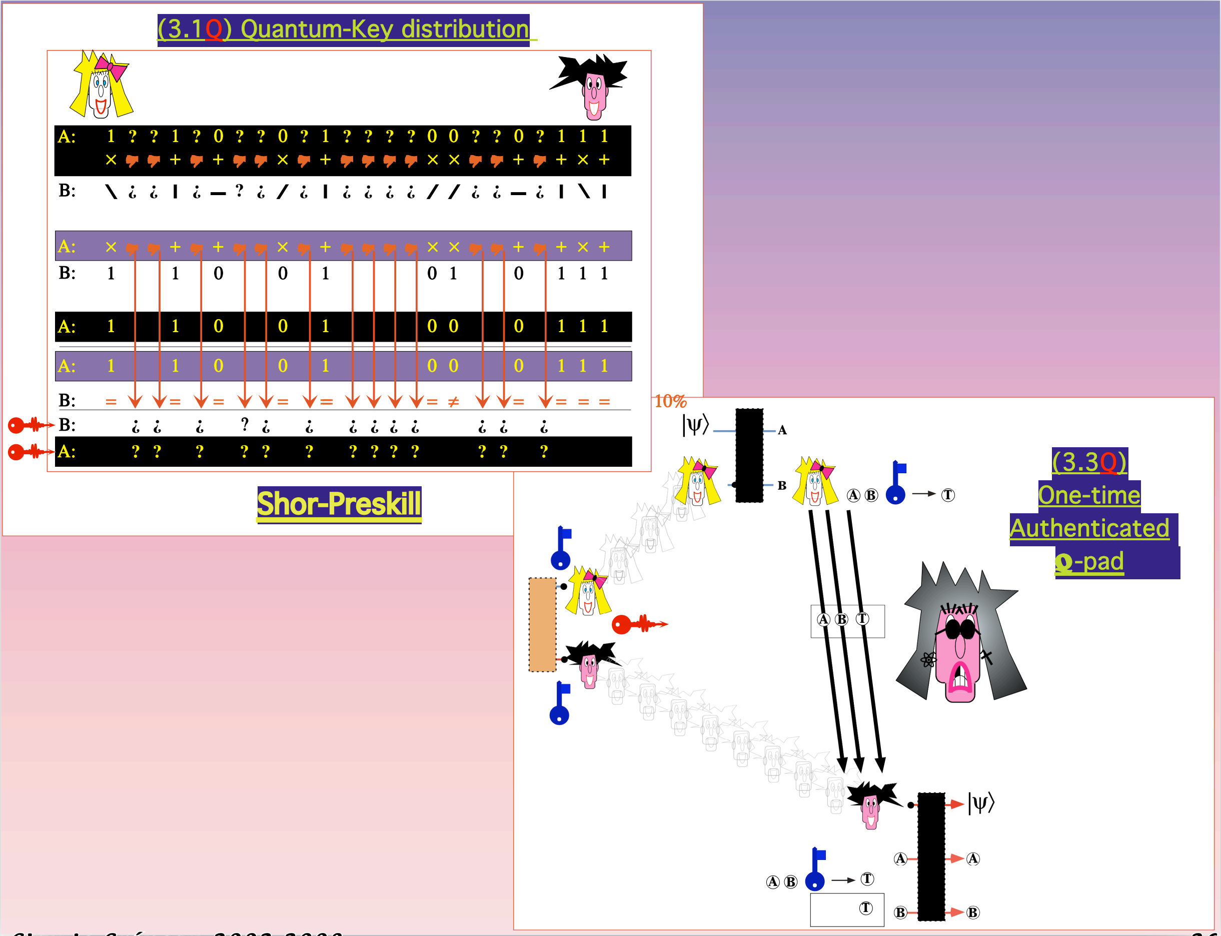
Completeness:



Soundness:



$$\forall|\psi\rangle\ \mathrm{Tr}(R_{|\psi\rangle}\rho)\geq 1-2^{-\Omega(s)}$$



(3.1Q) Quantum-Key distribution

A:	1	?	?	1	?	0	?	?	0	?	1	?	?	?	?	0	0	?	?	0	?	1	1	1
	×	👎	👎	+	👎	+	👎	👎	×	👎	+	👎	👎	👎	👎	×	×	👎	👎	+	👎	+	×	+
B:	\	¿	¿	|	¿	—	?	¿	/	¿	|	¿	¿	¿	¿	/	/	¿	¿	—	¿	|	\	|
A:	×	👎	👎	+	👎	+	👎	👎	×	👎	+	👎	👎	👎	👎	×	×	👎	👎	+	👎	+	×	+
B:	1			1		0			0		1					0	1			0		1	1	1
A:	1			1		0			0		1					0	0			0		1	1	1
A:	1			1		0			0		1					0	0			0		1	1	1
B:	=	↓	↓	=	↓	=	↓	↓	=	↓	=	↓	↓	↓	↓	=	≠	↓	↓	=	↓	=	=	=
B:		¿	¿		¿		?	¿		¿		¿	¿	¿	¿			¿	¿		¿			
A:		?	?		?		?	?		?		?	?	?	?			?	?		?			

10%

Shor-Preskill

(3.3Q) One-time Authenticated Q-pad

(3.3C) One-time interactive Q-Authentication

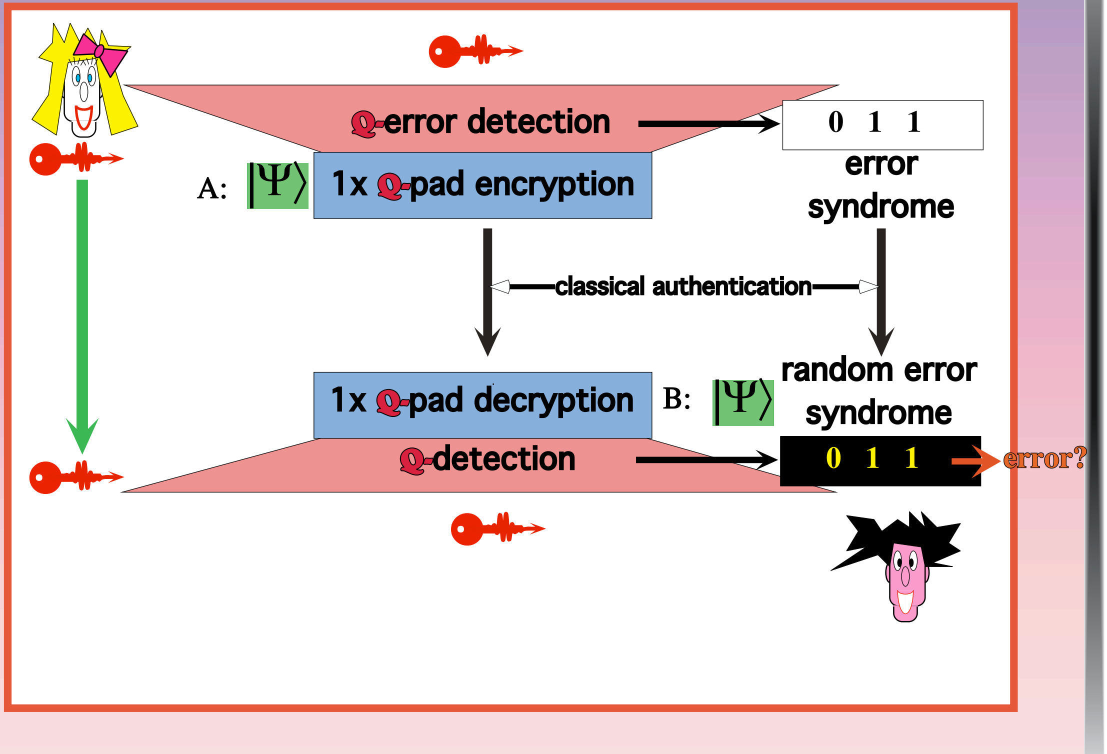
.....

- Transmit quantum key (EPR states)
- Quantum error-correction is used to purify (or test purity of) EPR states to form a smaller pure set

- one-time Authenticated Quantum pad is used to send message

.....

(3.3C) One-time interactive Q-Authentication



Q-error detection

0 1 1

error syndrome

A: $|\Psi\rangle$

1x Q-pad encryption

classical authentication

1x Q-pad decryption

B: $|\Psi\rangle$

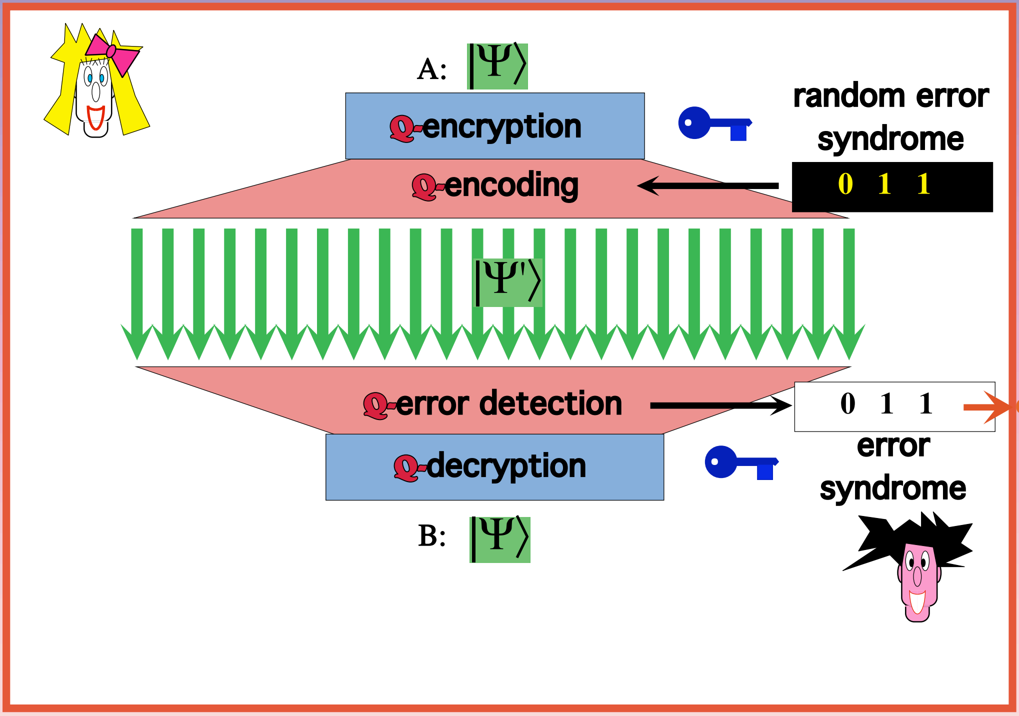
random error syndrome

Q-detection

0 1 1

error?

(3.1.3a) One-time Q-Authentication



A: |Ψ⟩

Q-encryption

random error syndrome

0 1 1

Q-encoding

|Ψ'⟩

Q-error detection

0 1 1

error?

error syndrome

Q-decryption

B: |Ψ⟩

Barnum-Crépeau-Gottesman-Smith-Tapp

(3.1.3a) One-time Q-Authentication

Classical key : one-time Q-authentication

Quantum message+tag

Quantum key : Authenticated Q-teleportation

Classical message+tag

|Ψ⟩

|Ψ'⟩

- public Q-error-correcting code
- secret key for encryption & syndrome

Barnum-Crépeau-Gottesman-Smith-Tapp

one-time Q-authentication

➔

Vernam Q-cipher

(authenticated quantum messages must be encrypted which is false for classical messages!)

Main Lower Bound

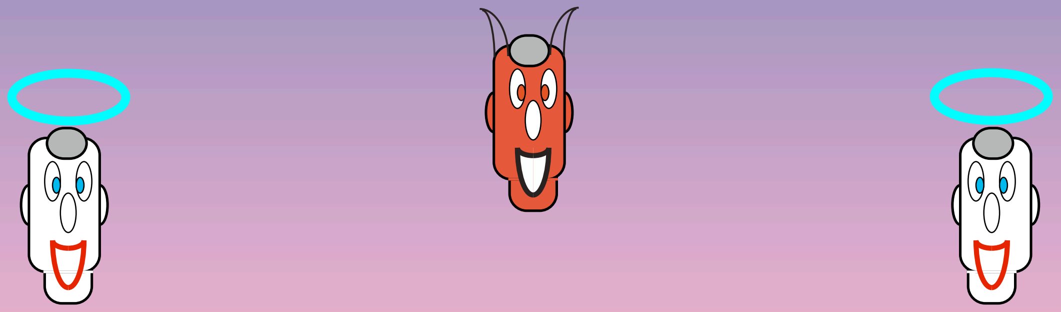
A Quantum Authentication Scheme with error probability ε

is

A Quantum Encryption Scheme with error probability $4\varepsilon^{1/6}$.

(3.2)
Complexity Theoretical Quantum Cryptography

(3.2) Complexity Theoretical Cryptography



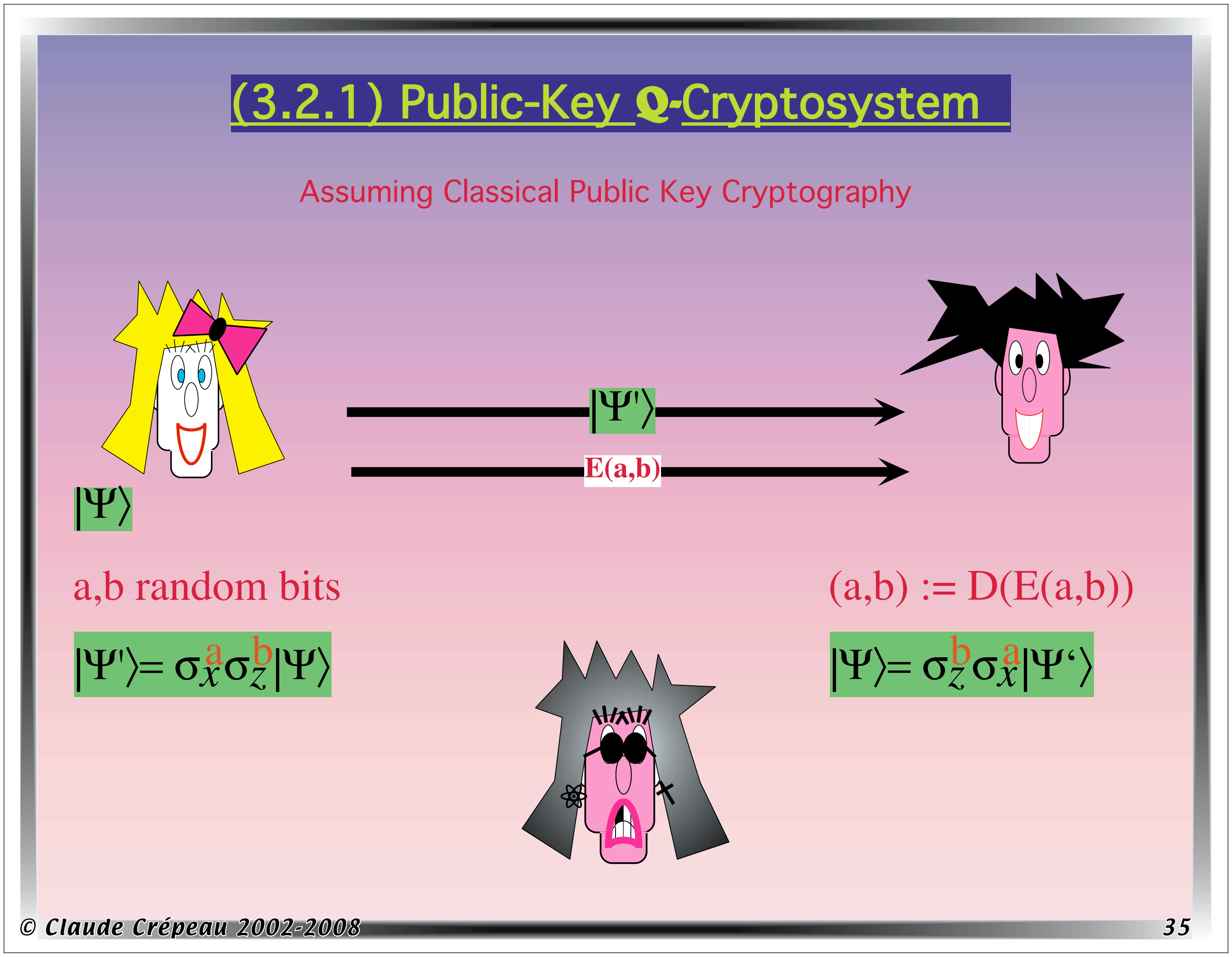
• • • • •

(3.2.1) Public key cryptosystem : public-key Q-cryptosystem

(3.2.2) Digital signature scheme : public-key Q-Authentication
Q-digital signature scheme

(3.2.3) (trapdoor) one-way functions : Q-cryptanalysis
(trapdoor) Q-one-way functions

• • • • •



(3.2.1) Public-Key Q-Cryptosystem

Assuming Classical Public Key Cryptography

$|\Psi'\rangle$

E(a,b)

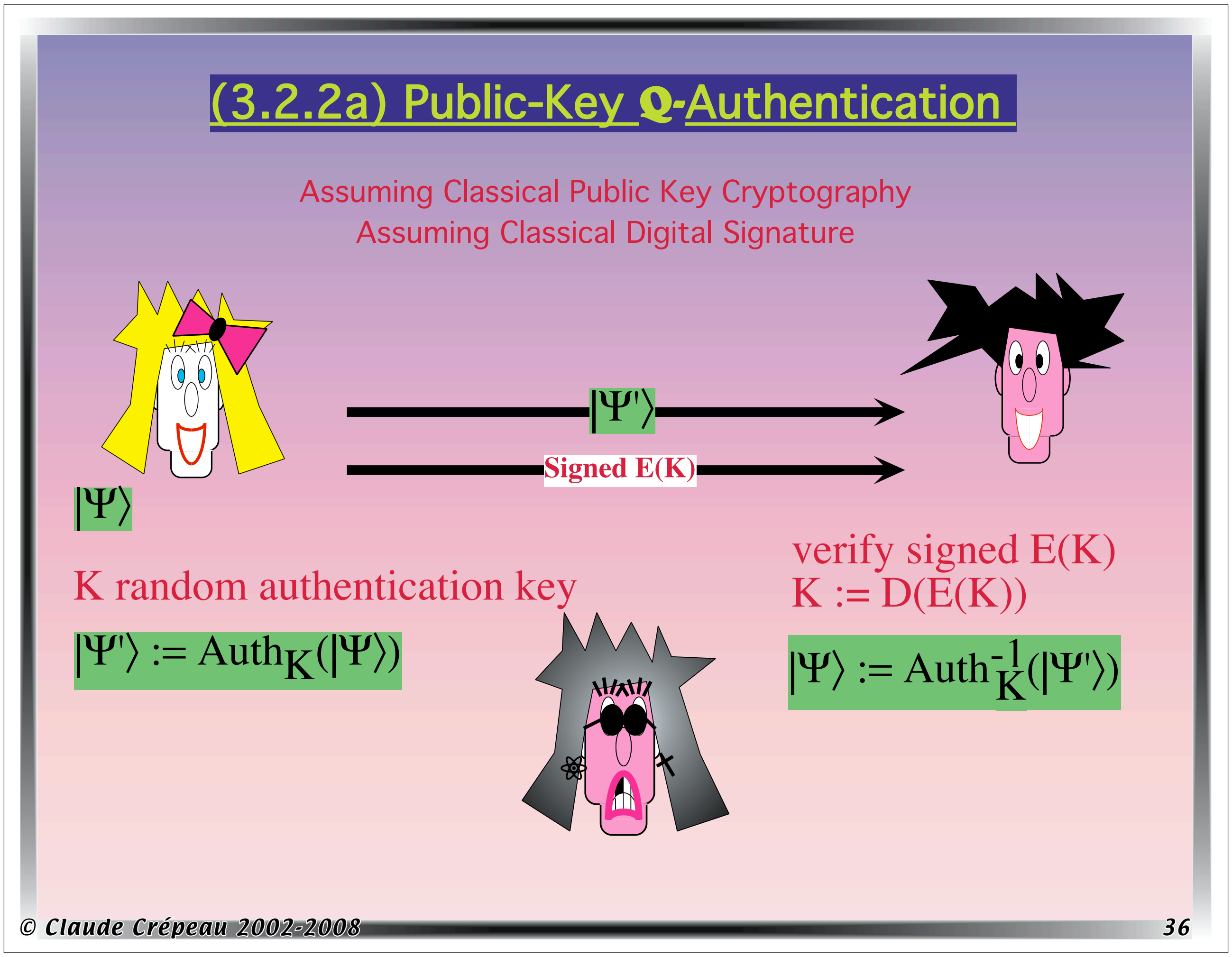
$|\Psi\rangle$

a,b random bits

$|\Psi'\rangle = \sigma_x^a \sigma_z^b |\Psi\rangle$

(a,b) := D(E(a,b))

$|\Psi\rangle = \sigma_z^b \sigma_x^a |\Psi'\rangle$



(3.2.2a) Public-Key Q-Authentication

Assuming Classical Public Key Cryptography
Assuming Classical Digital Signature

$|\Psi'\rangle$

Signed E(K)

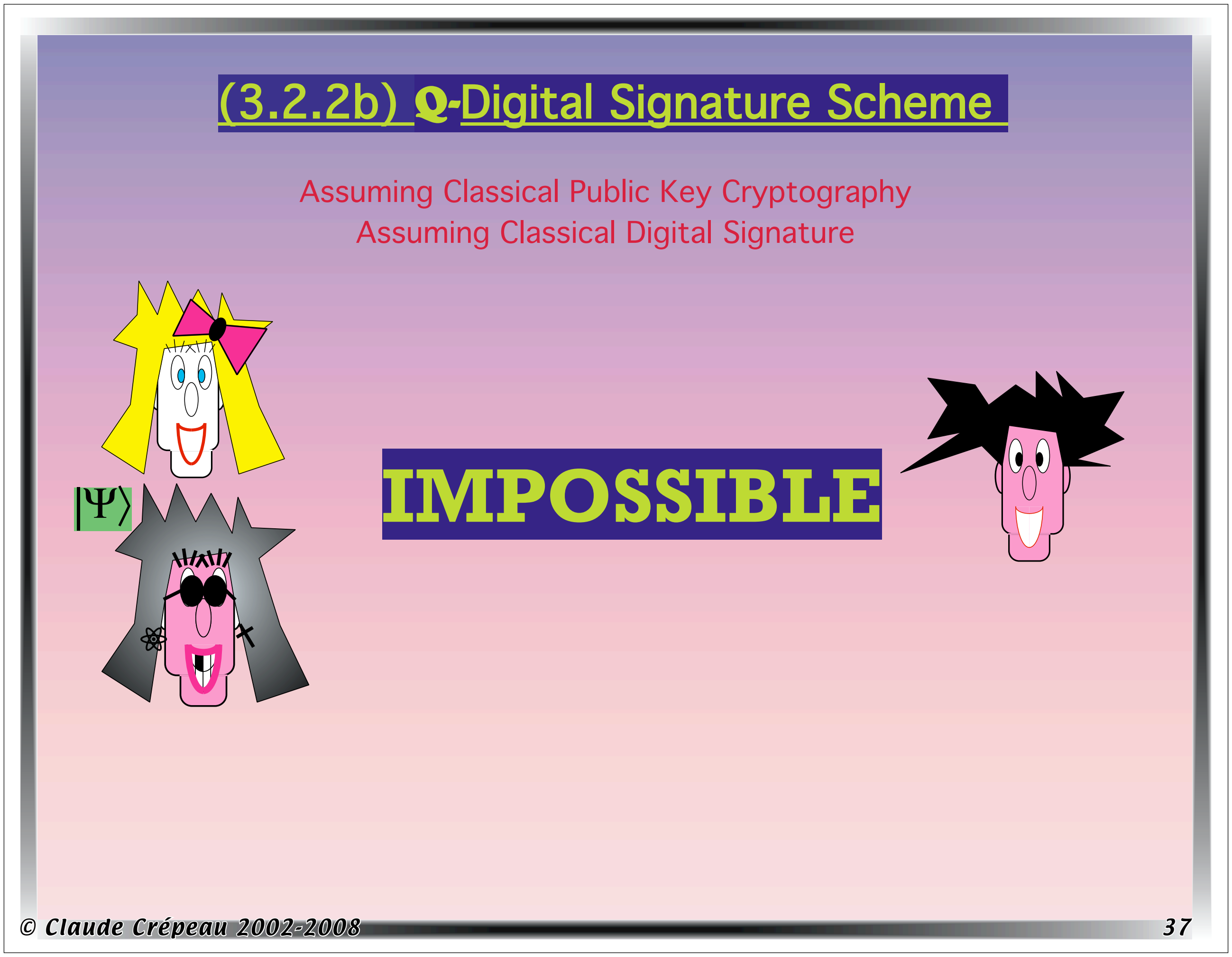
$|\Psi\rangle$

K random authentication key

$|\Psi'\rangle := \mathrm{Auth}_K(|\Psi\rangle)$

verify signed E(K)
K := D(E(K))

$|\Psi\rangle := \mathrm{Auth}_K^{-1}(|\Psi'\rangle)$

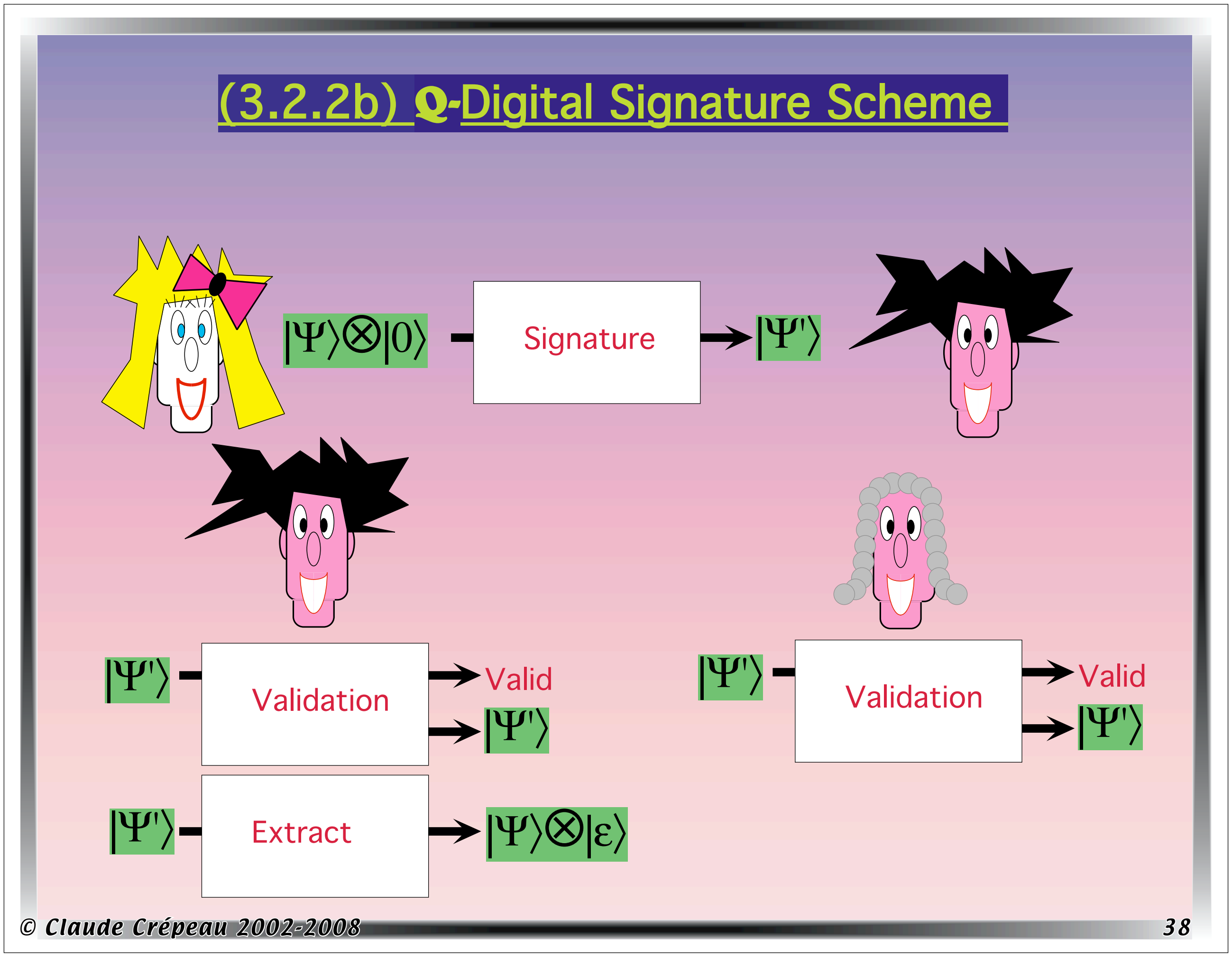


(3.2.2b) Q-Digital Signature Scheme

Assuming Classical Public Key Cryptography
Assuming Classical Digital Signature

$|\Psi\rangle$

IMPOSSIBLE



(3.2.2b) Q-Digital Signature Scheme

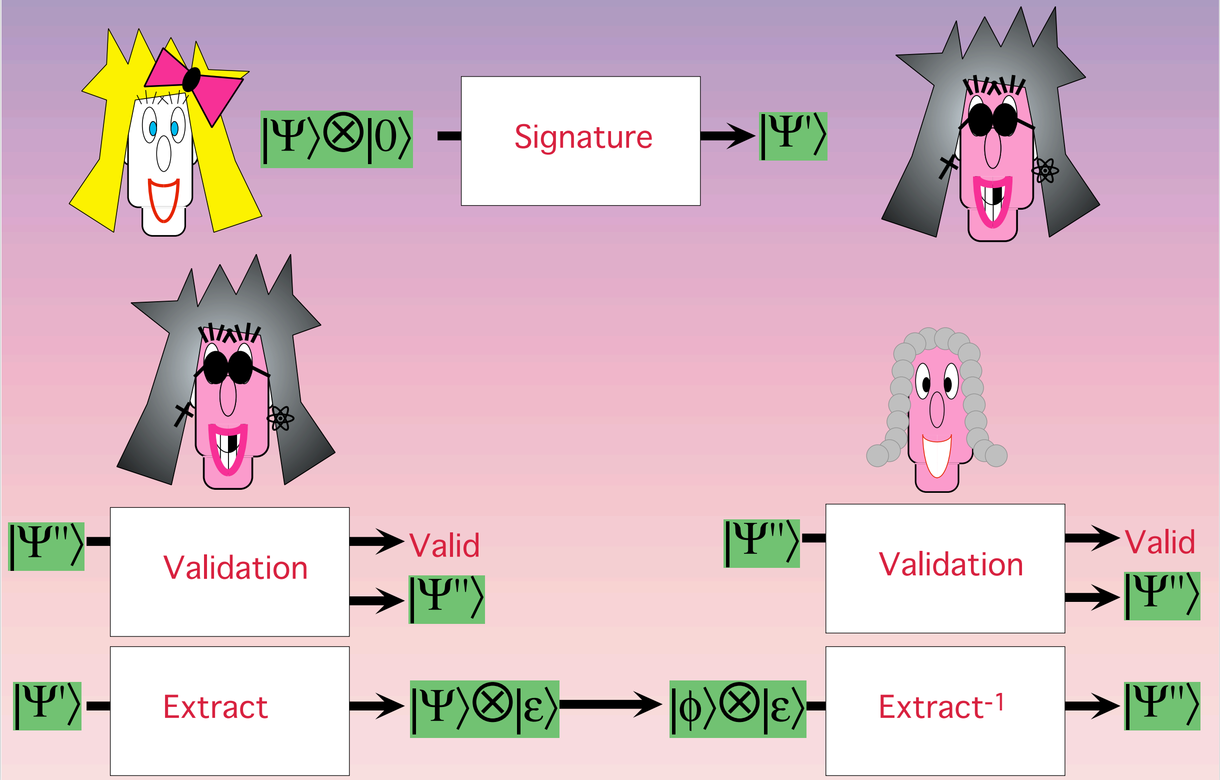
$|\Psi\rangle\otimes|0\rangle$ → Signature → $|\Psi'\rangle$

$|\Psi'\rangle$ → Validation → Valid, $|\Psi'\rangle$

$|\Psi'\rangle$ → Extract → $|\Psi\rangle\otimes|\varepsilon\rangle$

$|\Psi'\rangle$ → Validation → Valid, $|\Psi'\rangle$

(3.2.2b) Q-Digital Signature Scheme



$|\Psi\rangle\otimes|0\rangle$ Signature $|\Psi'\rangle$

$|\Psi''\rangle$ Validation Valid $|\Psi''\rangle$

$|\Psi''\rangle$ Validation Valid $|\Psi''\rangle$

$|\Psi'\rangle$ Extract $|\Psi\rangle\otimes|\varepsilon\rangle$ $|\phi\rangle\otimes|\varepsilon\rangle$ Extract^{-1} $|\Psi''\rangle$

(3.2.3) (Trapdoor) Q-One-way functions

- generate a function f (and trapdoor) s.t.
- computing f(x) is easy
- finding x s.t. f(x)=y is hard
- finding x s.t. f(x)=y is easy with trapdoor

Q-cryptanalysis : Shor

Q-One-way function

Fischer-Stern
one-way function
(error correction code based)

generation : classical easy
computing f : classical easy
inverting f : classical /quantum hard ???

Trapdoor Q-One-way function

Okamoto-Tanaka-Uchiyama
trapdoor one-way permutation
(subset products problem based)

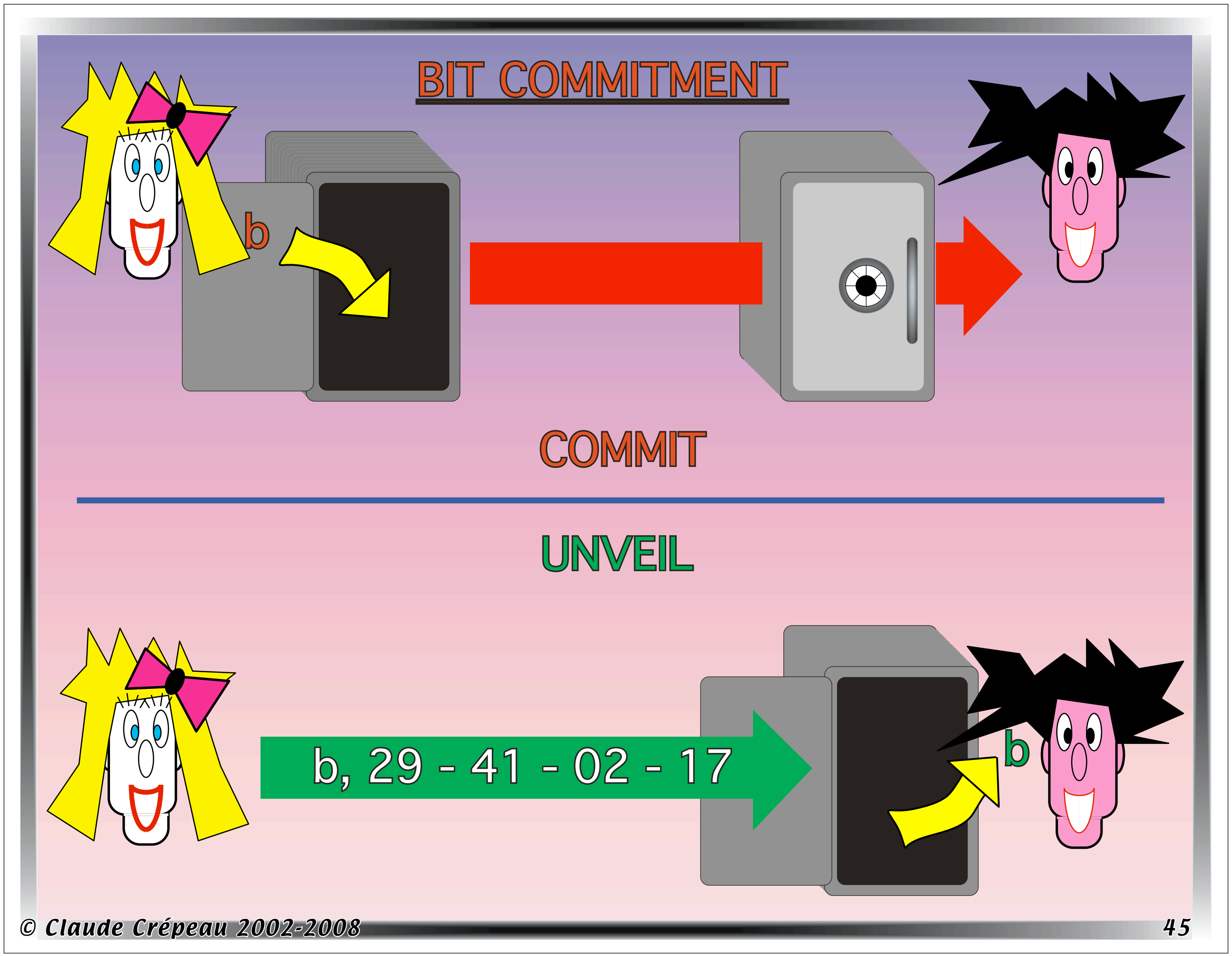
generation : quantum easy
computing f : classical easy
inverting f : classical /quantum hard ???
trapdooring f : classical easy

Trapdoor Q-One-way function

McEliece
trapdoor one-way permutation
(error correction code based)

generation : classical easy
computing f : classical easy
inverting f : classical /quantum hard ???
trapdooring f : classical easy

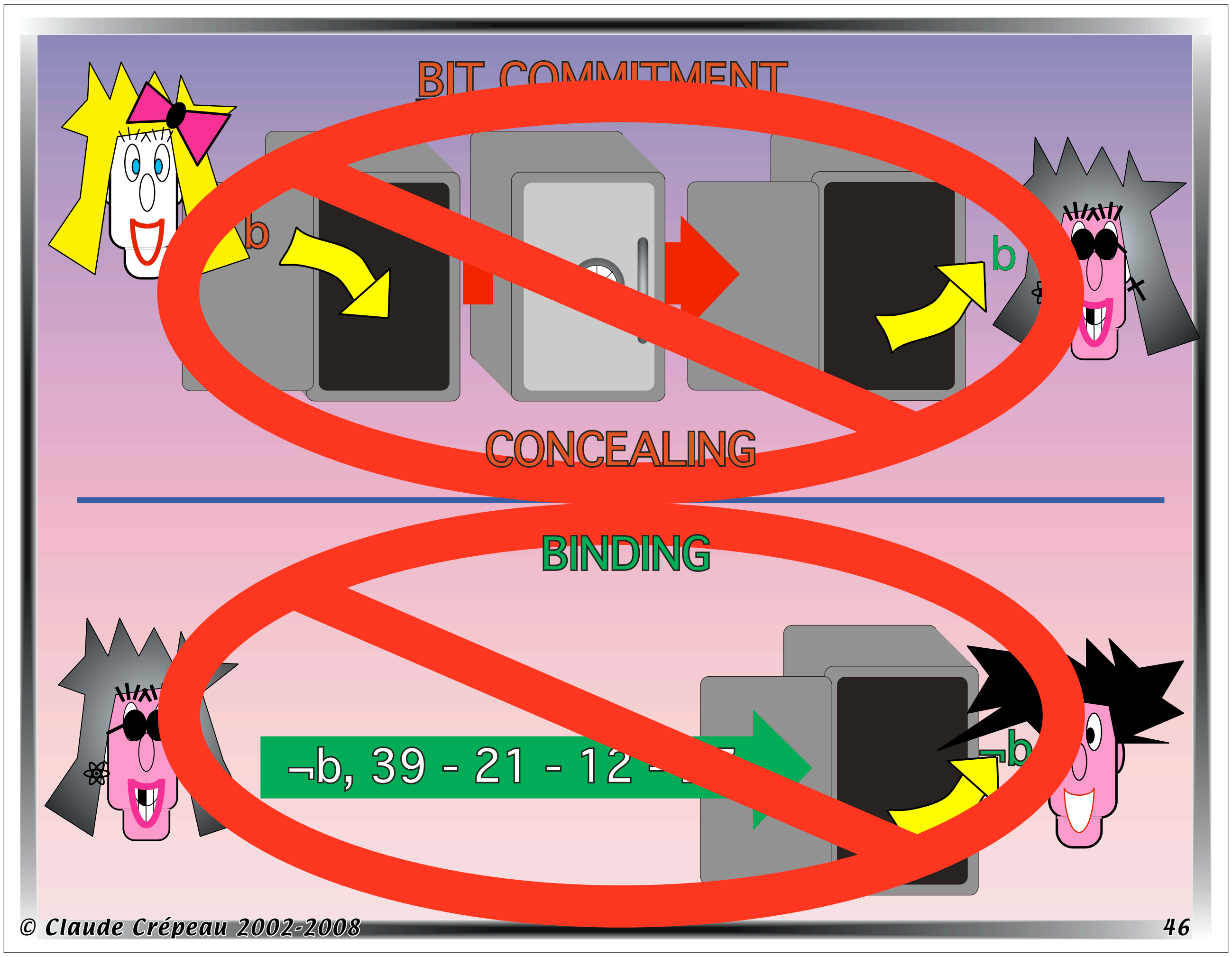
(4)
two-party
Cryptographic Protocols



BIT COMMITMENT

COMMIT

UNVEIL

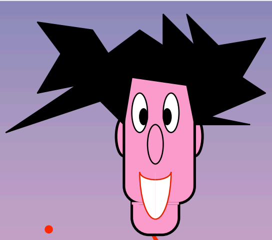


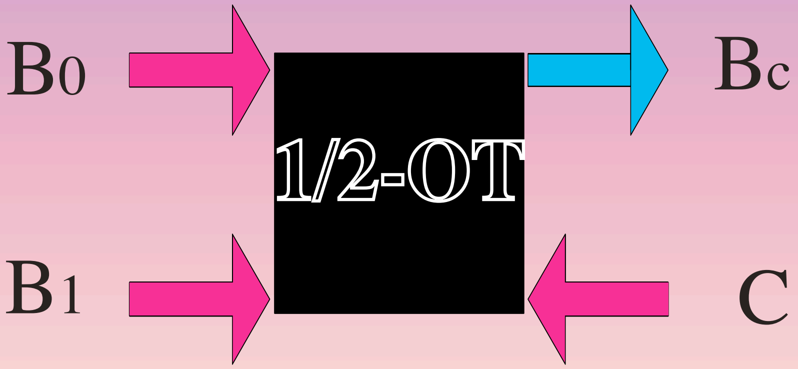
BIT COMMITMENT

CONCEALING

BINDING

Oblivious Transfer (message multiplexing)





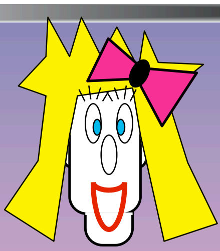
B0

B1

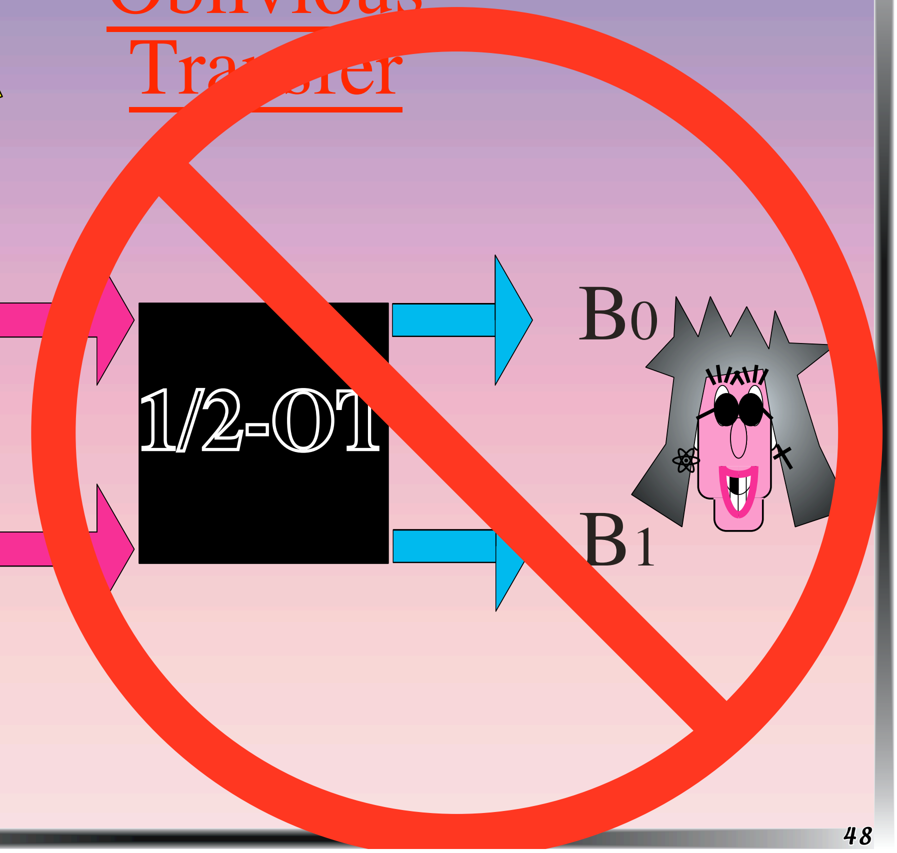
1/2-OT

Bc

C



Oblivious Transfer



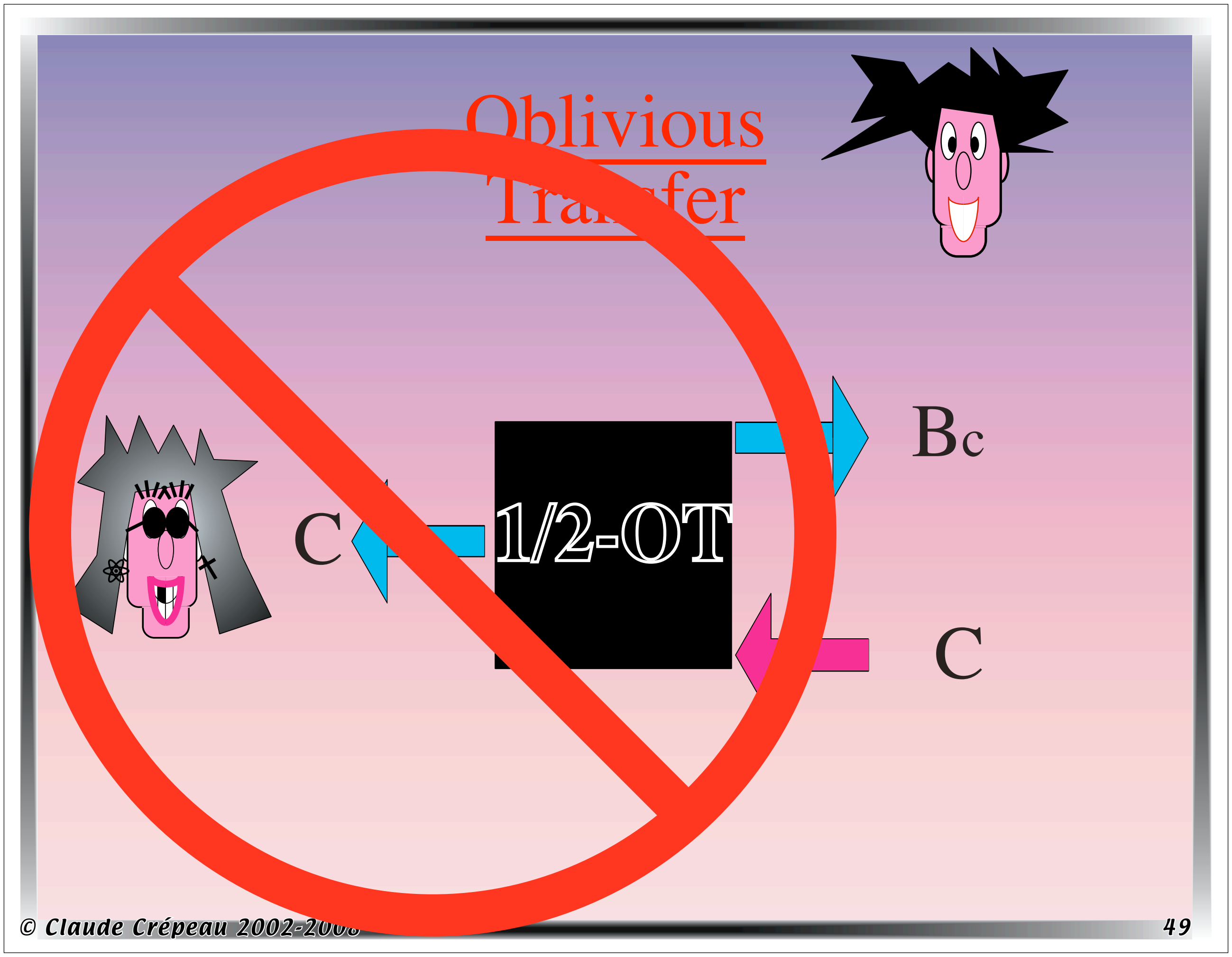
B0

B1

1/2-OT

B0

B1



Oblivious Transfer

Bc

C

1/2-OT

C

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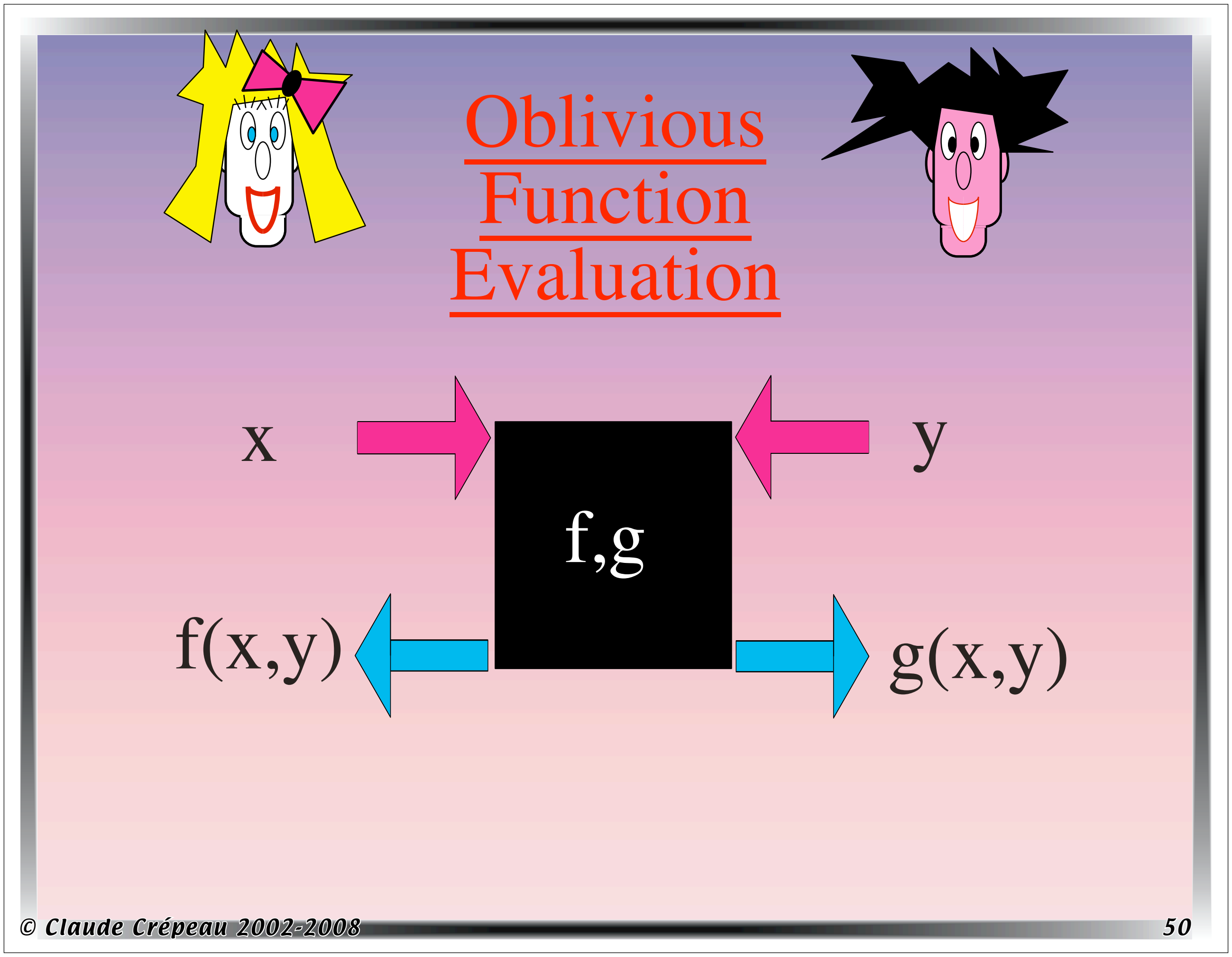


Oblivious Function Evaluation

x

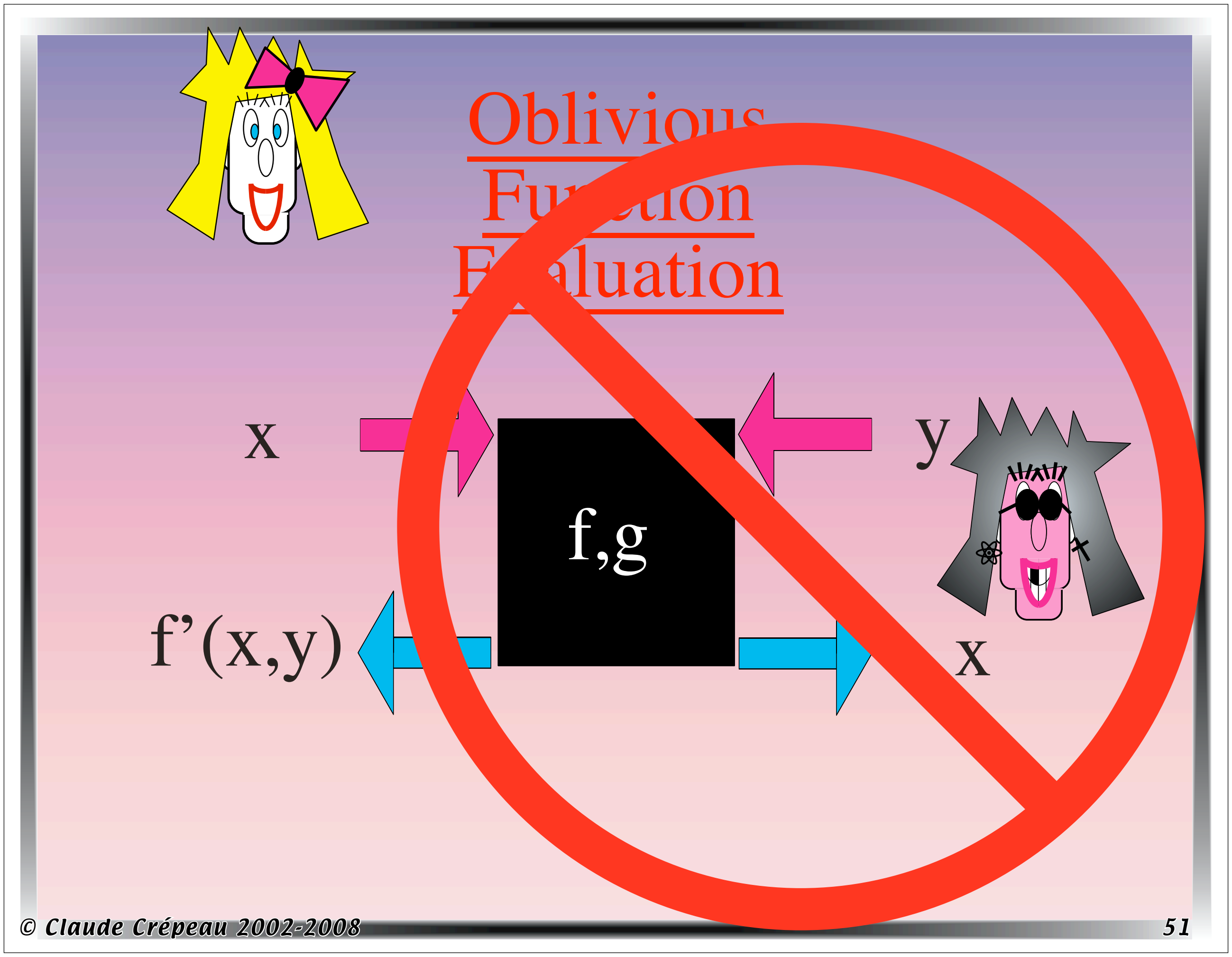
y

f,g

f(x,y)

g(x,y)

© Claude Crépeau 2002-2008



Oblivious Function Evaluation

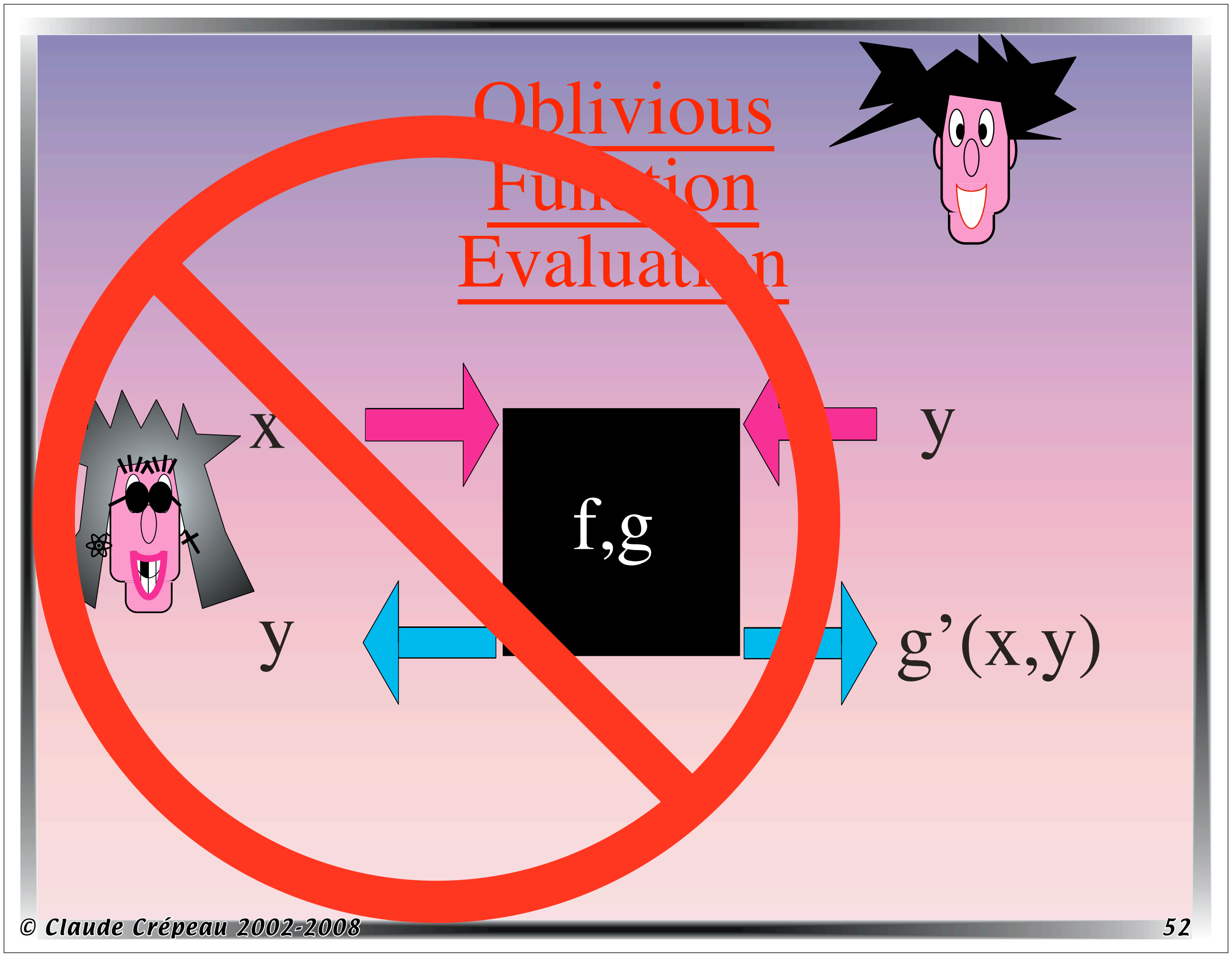
x

y

f,g

f’(x,y)

x



Oblivious Function Evaluation

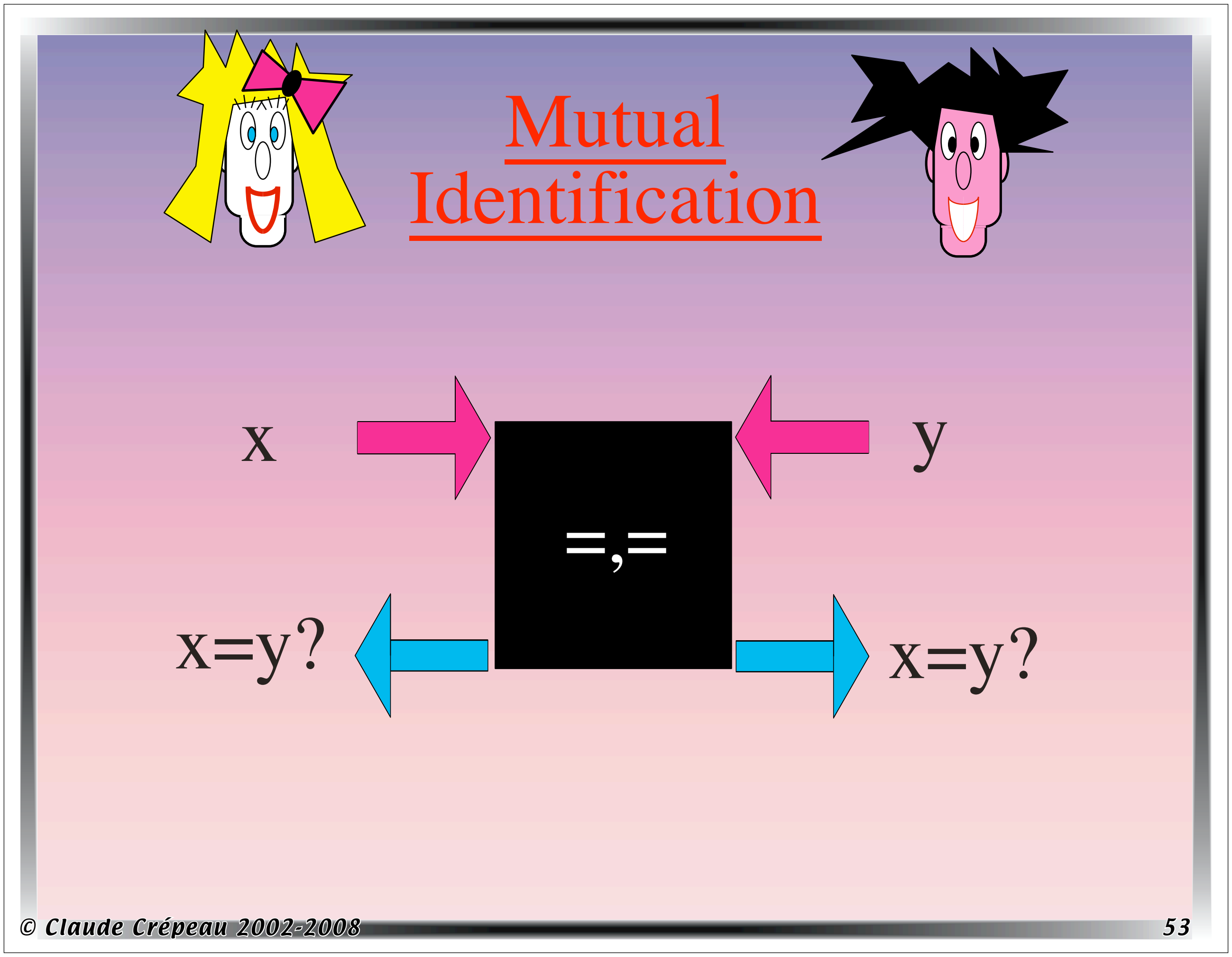
x

y

f,g

y

g’(x,y)



Mutual Identification

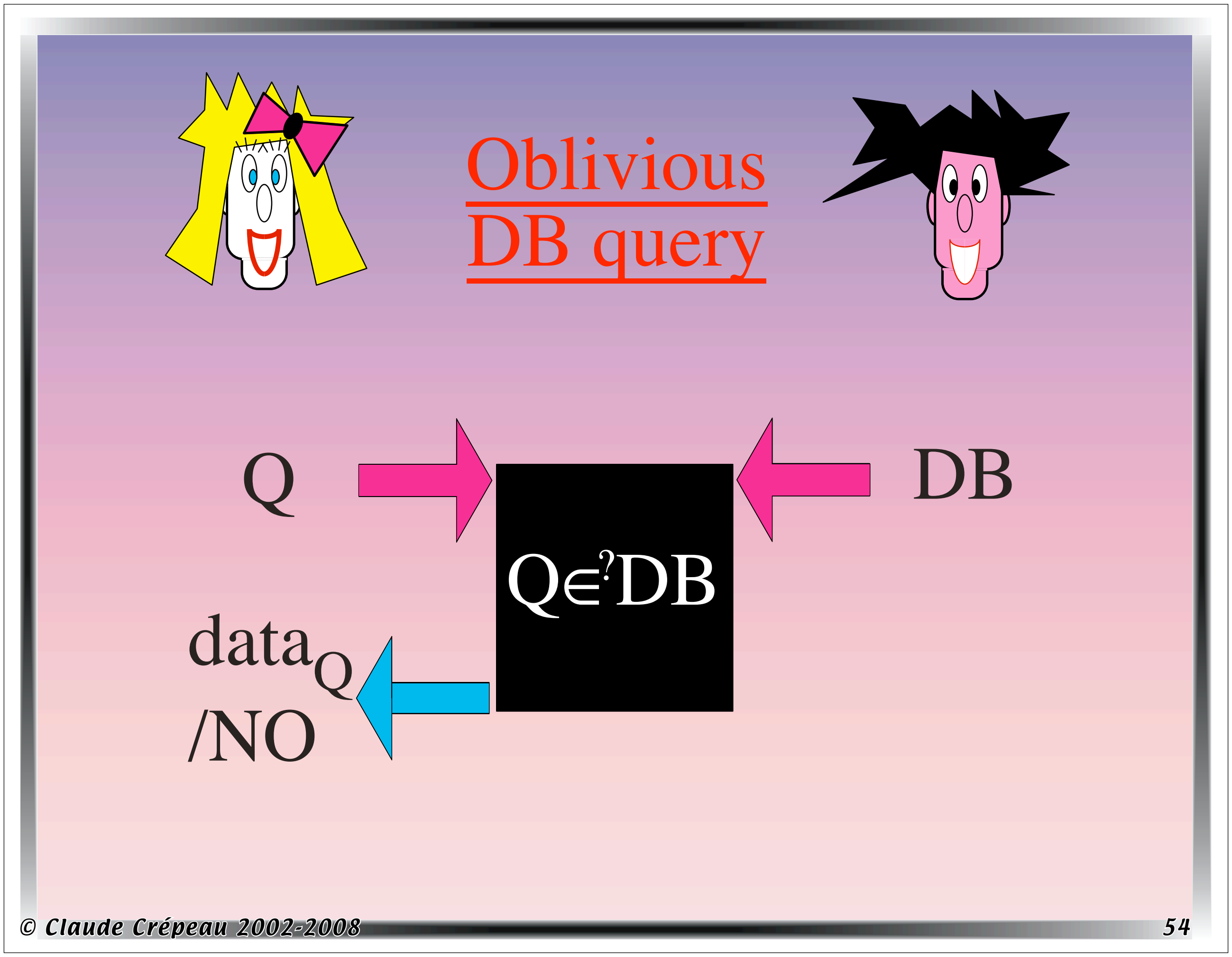
x

y

=,=

x=y?

x=y?



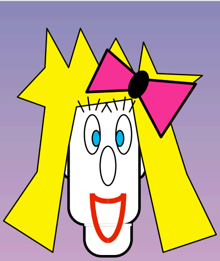
Oblivious DB query

Q

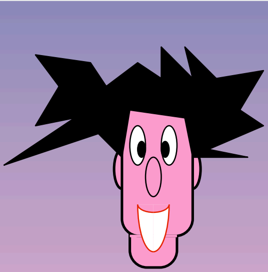
DB

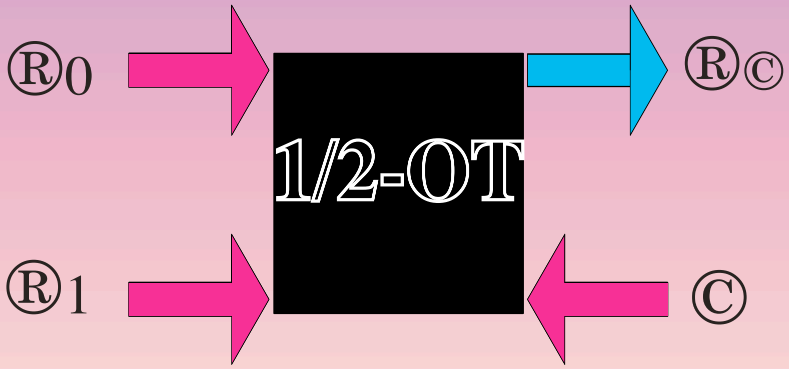
$Q \overset{?}{\in} DB$

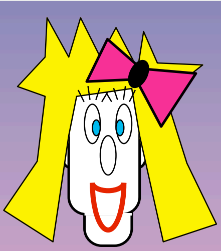
data_Q /NO



Randomized Oblivious Transfer







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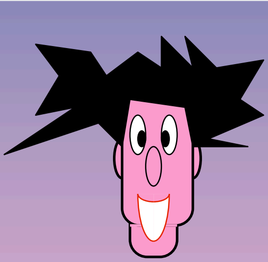
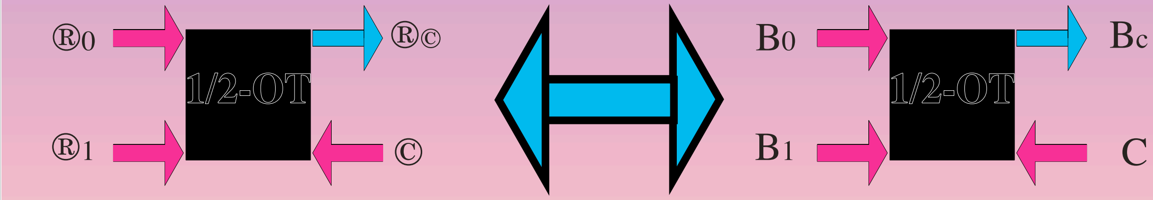
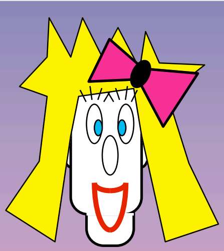
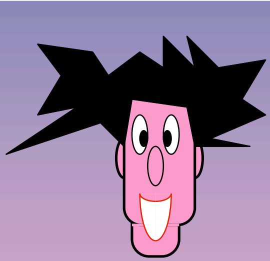
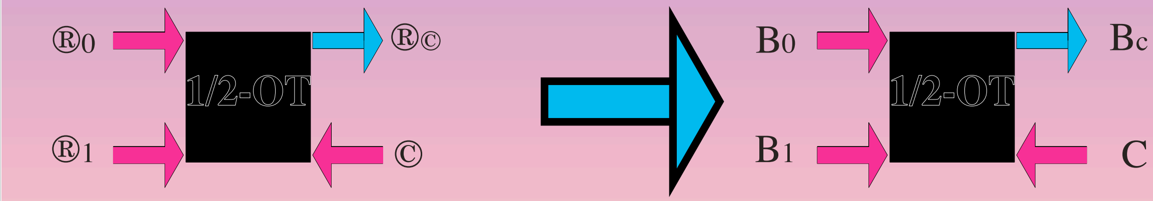




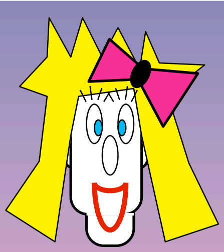
Randomized Oblivious Transfer

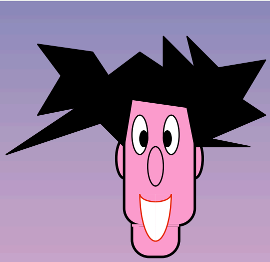


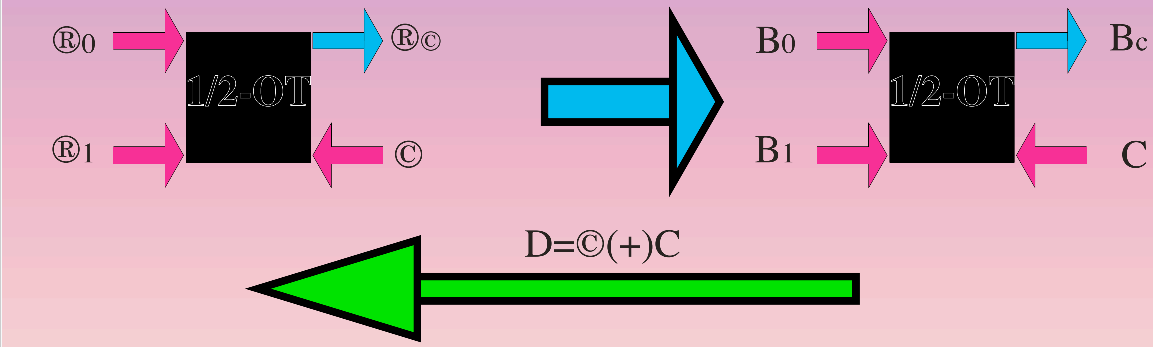


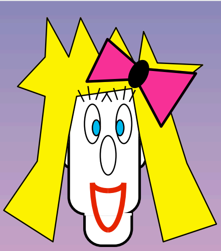


Randomized Oblivious Transfer

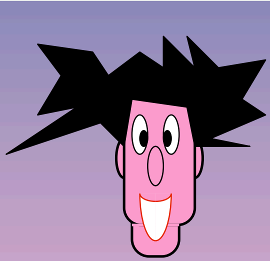


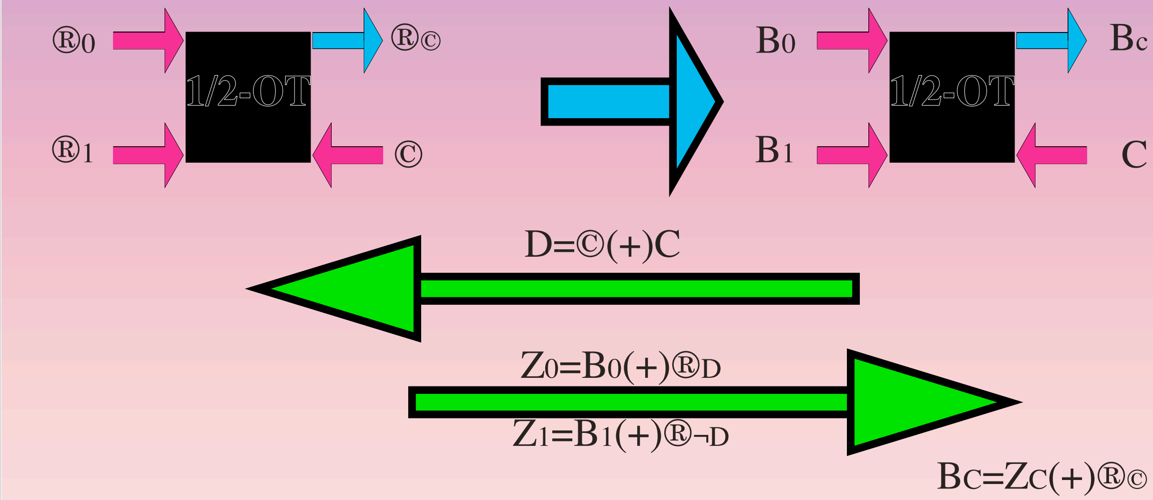


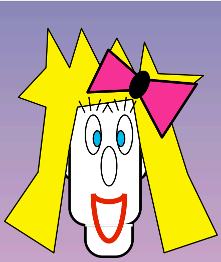




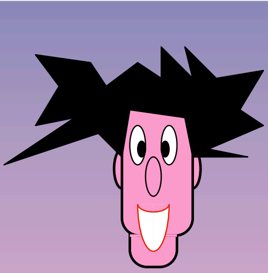
Randomized Oblivious Transfer

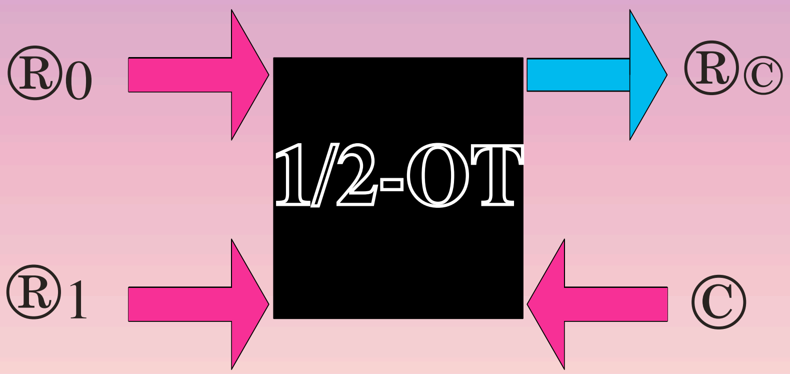




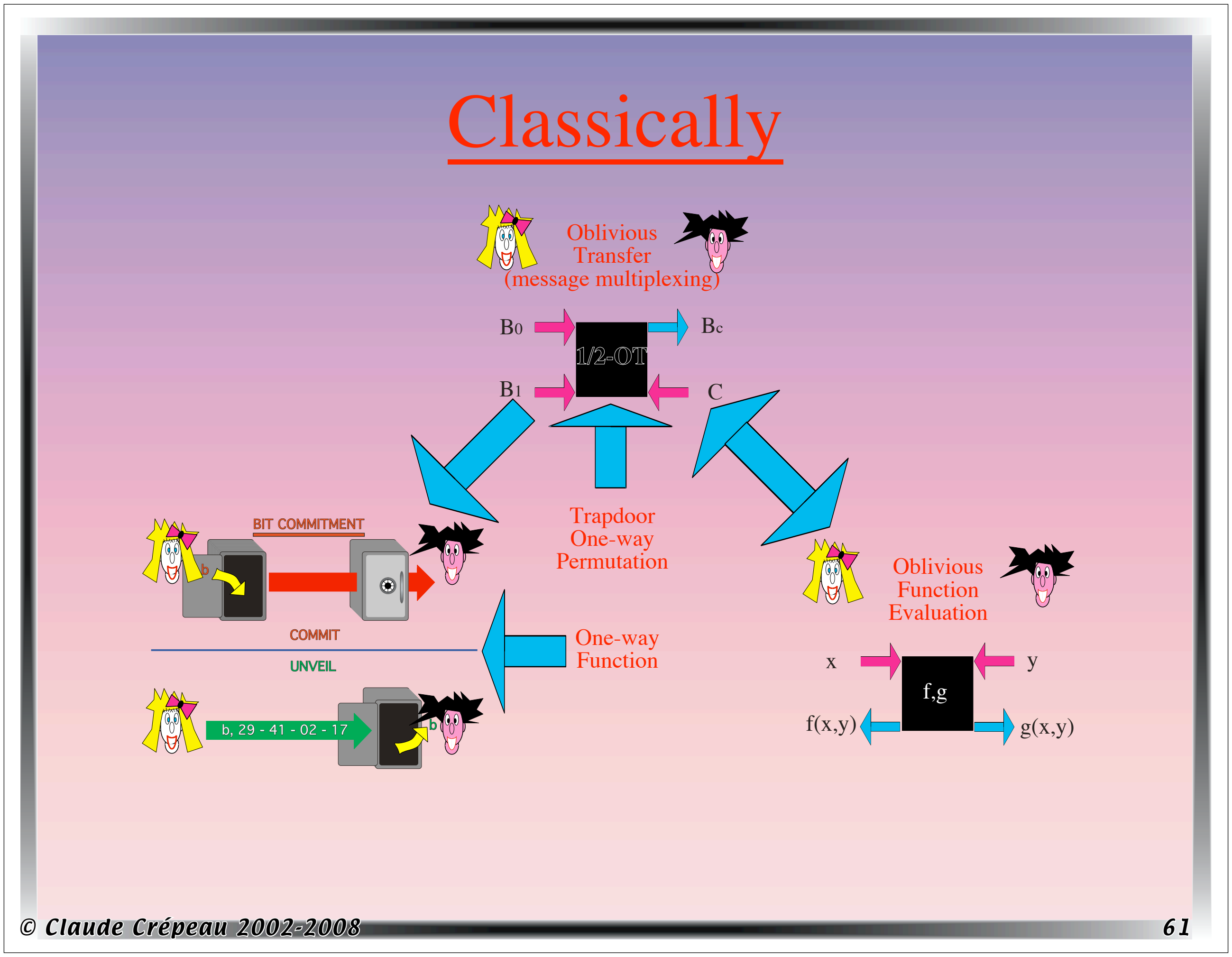


Randomized Oblivious Transfer





IS AN INVESTMENT IN THE FUTURE



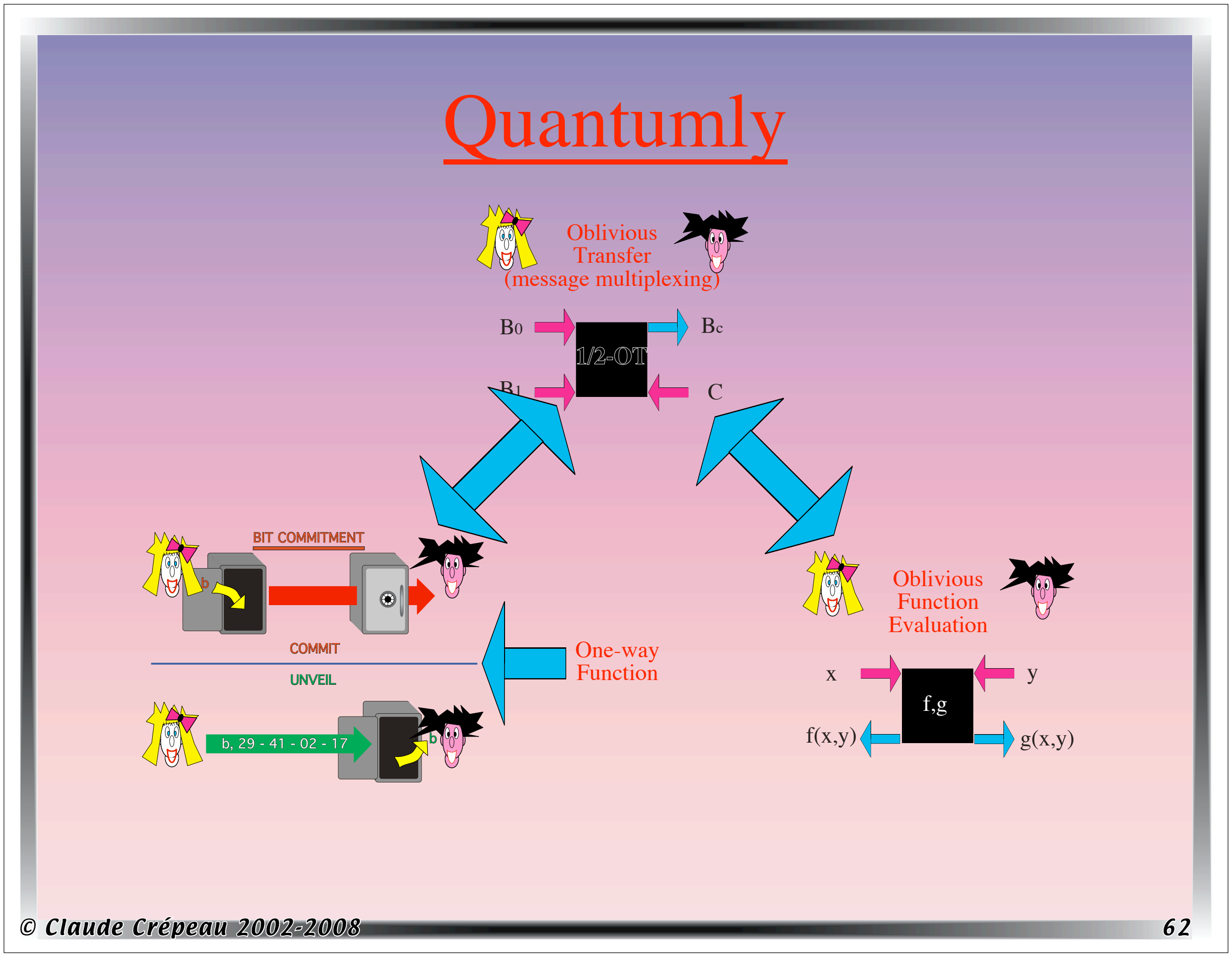
Classically

Oblivious Transfer (message multiplexing)

Trapdoor One-way Permutation

One-way Function

Oblivious Function Evaluation



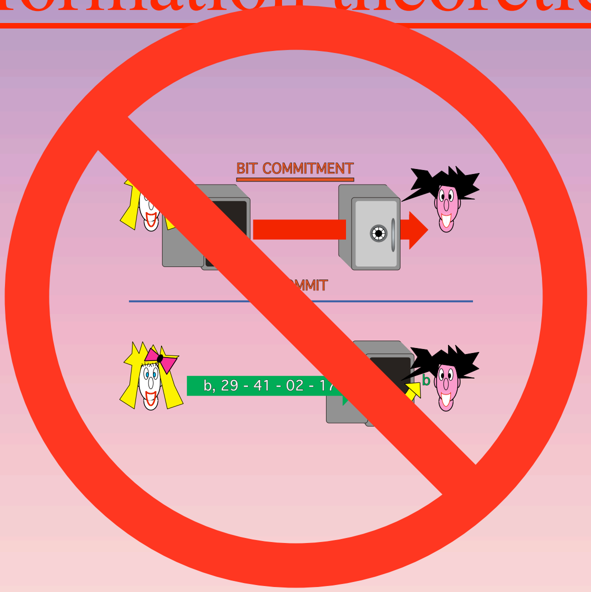
Quantumly

Oblivious Transfer (message multiplexing)

One-way Function

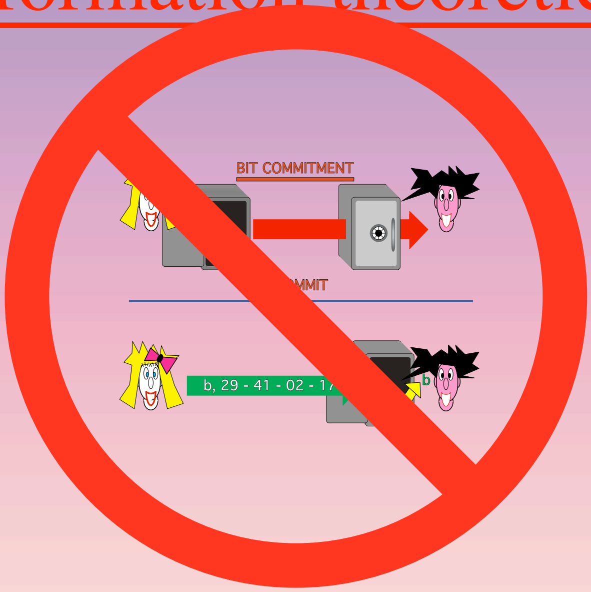
Oblivious Function Evaluation

Classically (information theoretical)



Folklore

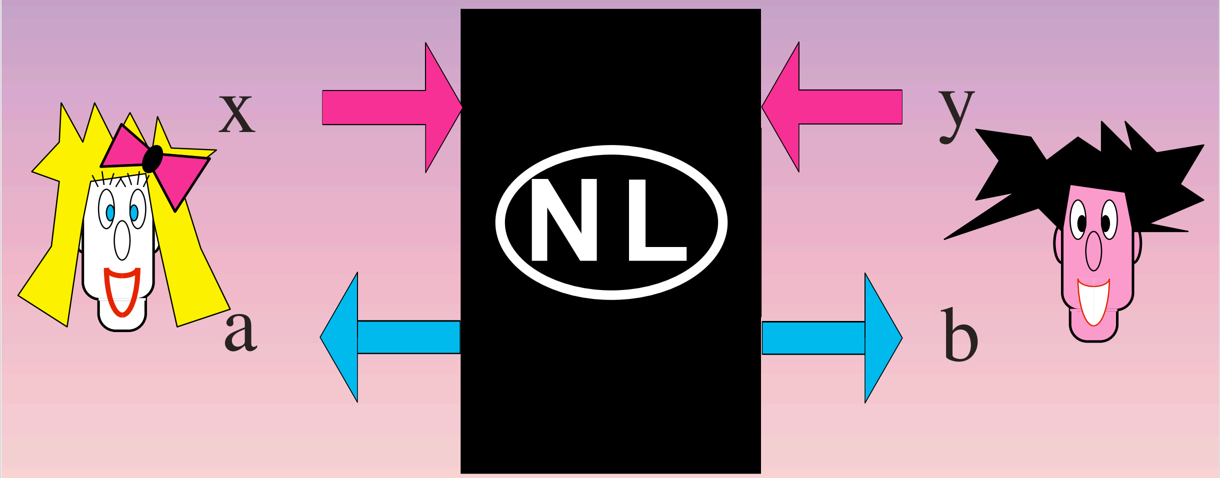
Quantumly (information theoretical)



Mayers, Lo-Chau

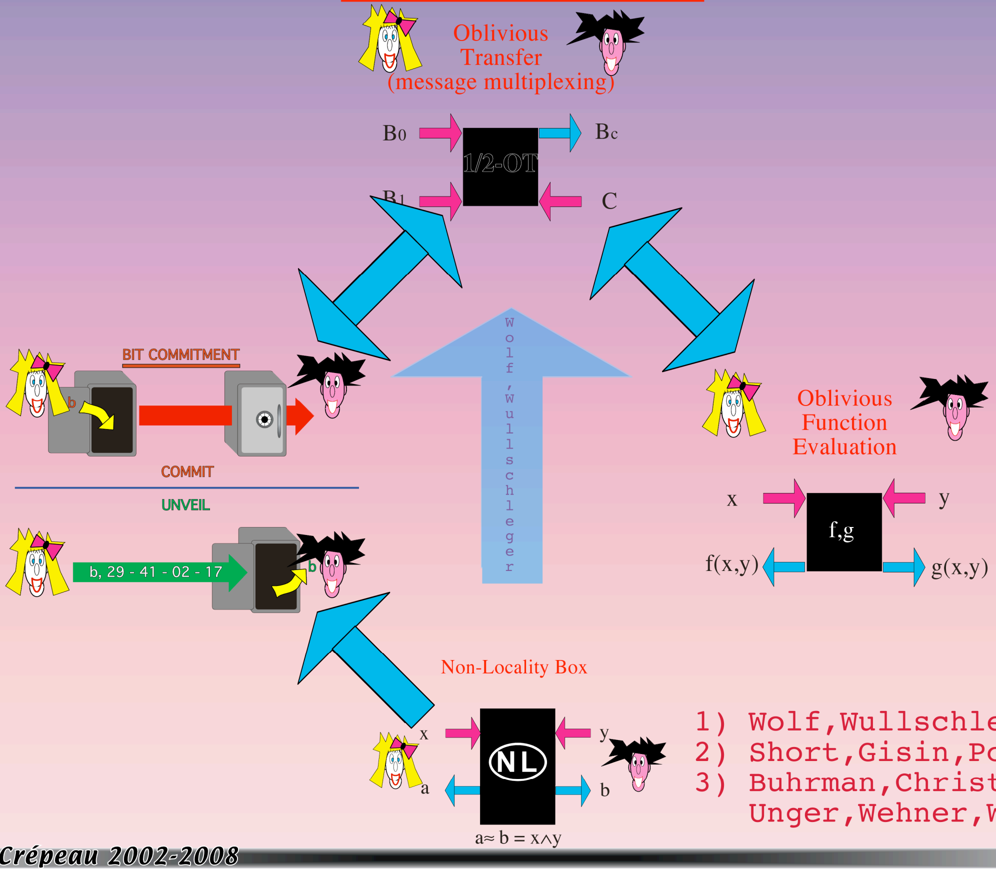
Non-Locality Box

$$a \oplus b = x \wedge y$$



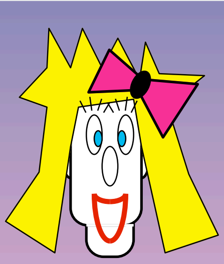
C: 3/4 Q: $\cos^2(\pi/8) \approx 85\%$

Quantumly

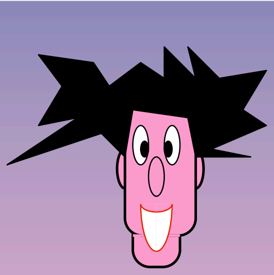


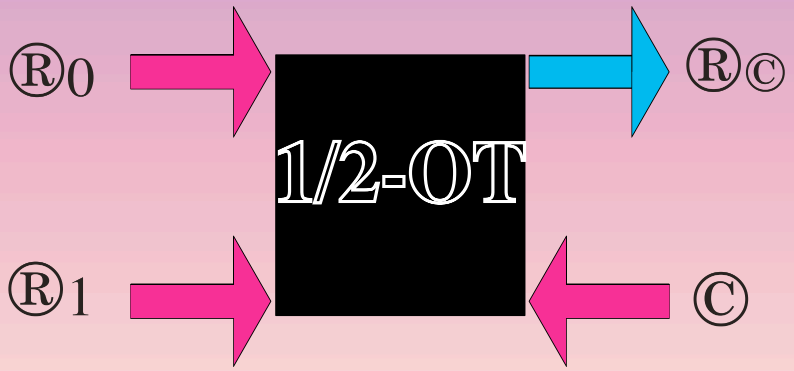
1) Wolf,Wullschleger ?
2) Short,Gisin,Popescu
3) Buhrman,Christandl,
   Unger,Wehner,Winter

(5) Quantum Oblivious Transfer

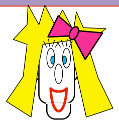


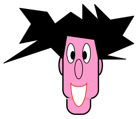
Randomized Oblivious Transfer





Q-ROT





A: 0 1 1 0 0 1 0 0 1 1 0 1 0 0 0 1 1 1 0 1 1 0 0 0
× + × + + + × × × × + + + + × × × + × + + + × +

B: × × + + × + + + × + + × × × + × × × + + × + × +
0 0 1 0 0 1 0 0 1 0 0 0 0 1 1 1 0 0 0 1 1 0 0 0

A: × + × + + + × × × × + + + + × × × + × + + + × +

B: 0 👎 👎 0 👎 1 👎 👎 1 👎 0 👎 👎 👎 👎 1 0 👎 👎 1 👎 0 0 0

B: 0 0 1 1 0 1 0 1 0 0 0 👎 👎 👎 👎 👎 👎 👎 👎 👎 👎 👎 👎 👎

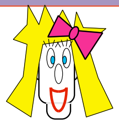
A: 0 0 1 1 0 1 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 0 1

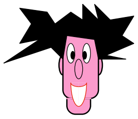
B: 0 0 1 1 0 1 0 1 = 0 👎 = 👎 👎 👎 👎 👎 👎 👎 👎

A: 0 0 1 1 0 1 0 1 = $0 = ®_0$ $®_1 = 0$ = 1 1 0 0 0 1 0 1

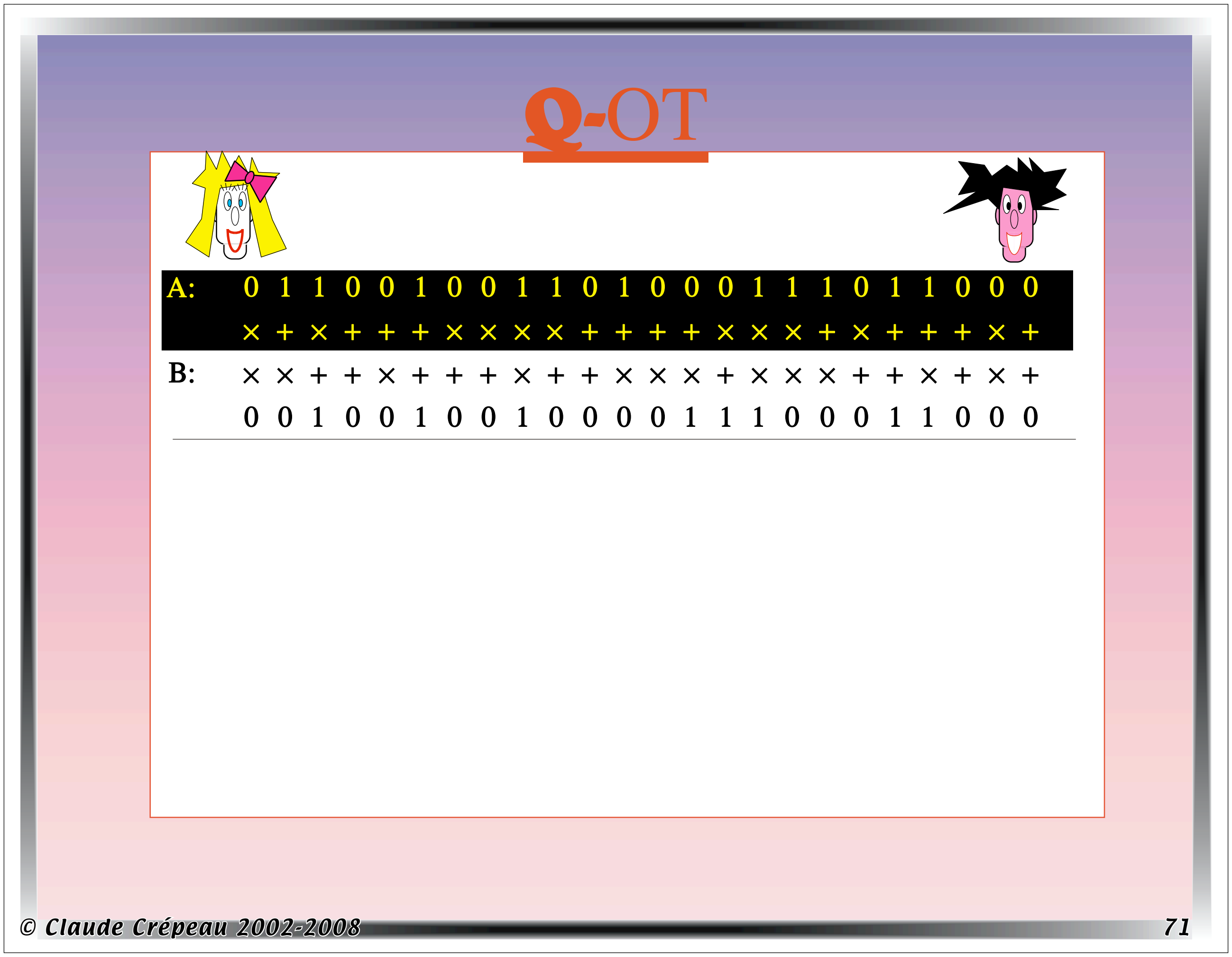
Crépeau-Kilian

Q-OT



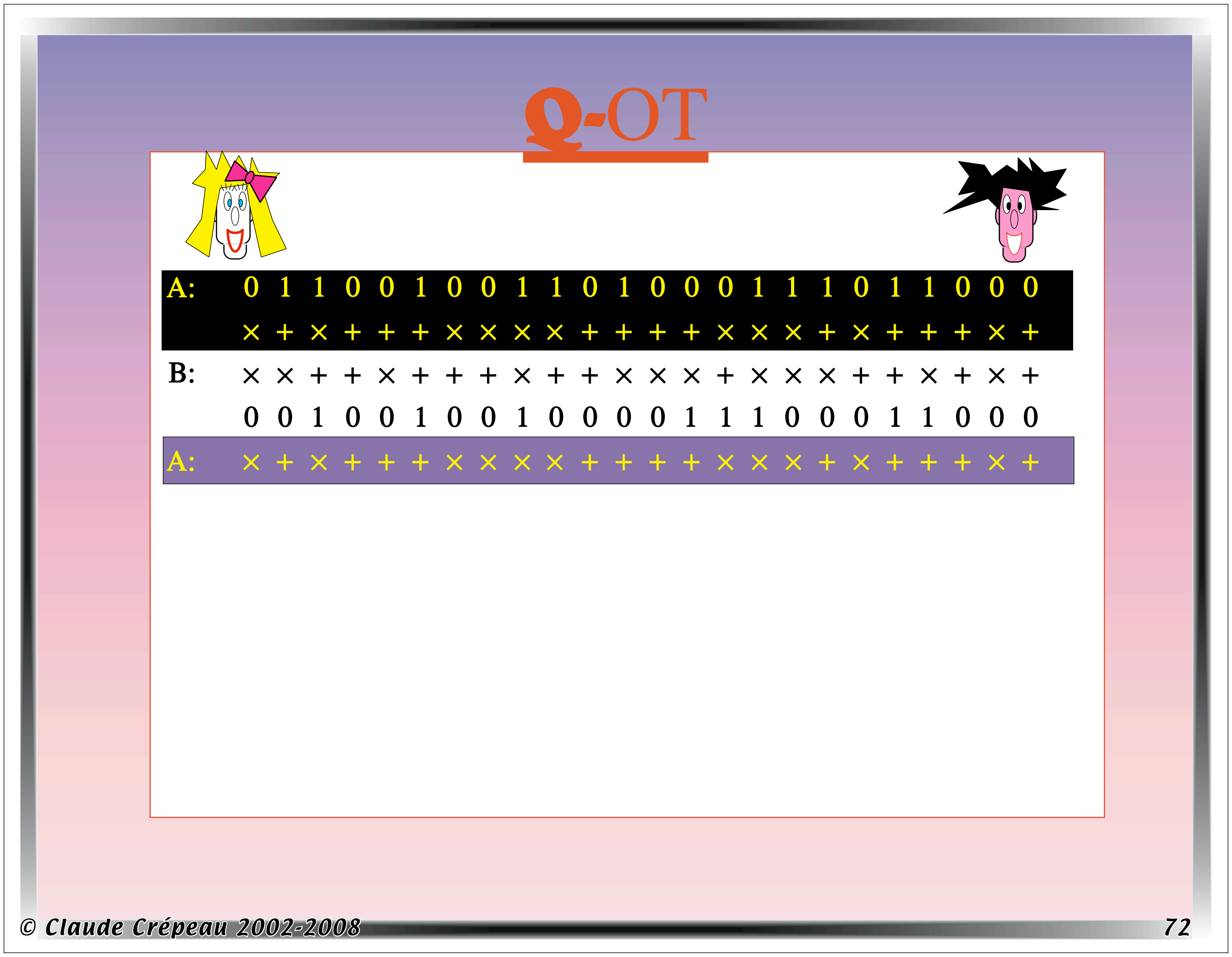


A: 0 1 1 0 0 1 0 0 1 1 0 1 0 0 0 1 1 1 0 1 1 0 0 0
× + × + + + × × × × + + + + × × × + × + + + × +



Q-OT

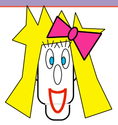
A:	0	1	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	1	0	0	0
	×	+	×	+	+	+	×	×	×	×	+	+	+	+	×	×	×	+	×	+	+	+	×	+
B:	×	×	+	+	×	+	+	+	×	+	+	×	×	×	+	×	×	×	+	+	×	+	×	+
	0	0	1	0	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0

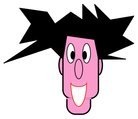


Q-OT

A:	0	1	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	1	0	0	0
	×	+	×	+	+	+	×	×	×	×	+	+	+	+	×	×	×	+	×	+	+	+	×	+
B:	×	×	+	+	×	+	+	+	×	+	+	×	×	×	+	×	×	×	+	+	×	+	×	+
	0	0	1	0	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0
A:	×	+	×	+	+	+	×	×	×	×	+	+	+	+	×	×	×	+	×	+	+	+	×	+

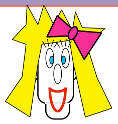
Q-OT

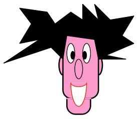




B:	×	×	+	+	×	+	+	+	×	+	+	×	×	×	+	×	×	×	+	+	×	+	×	+
	0	0	1	0	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0
A:	×	+	×	+	+	+	×	×	×	×	+	+	+	+	×	×	×	+	×	+	+	+	×	+
B:	0	👎	👎	0	👎	1	👎	👎	1	👎	0	👎	👎	👎	👎	1	0	👎	👎	1	👎	0	0	0

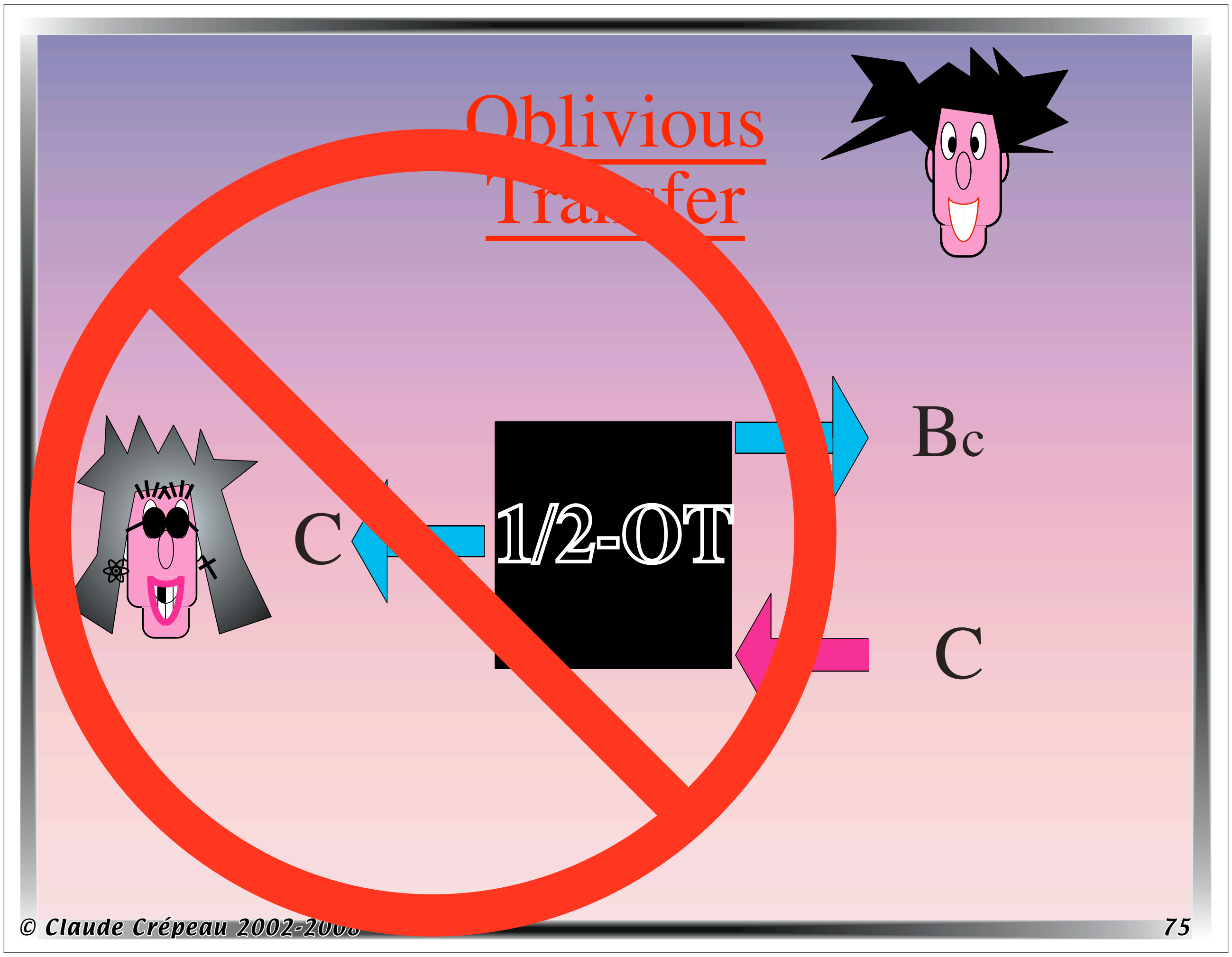
Q-OT



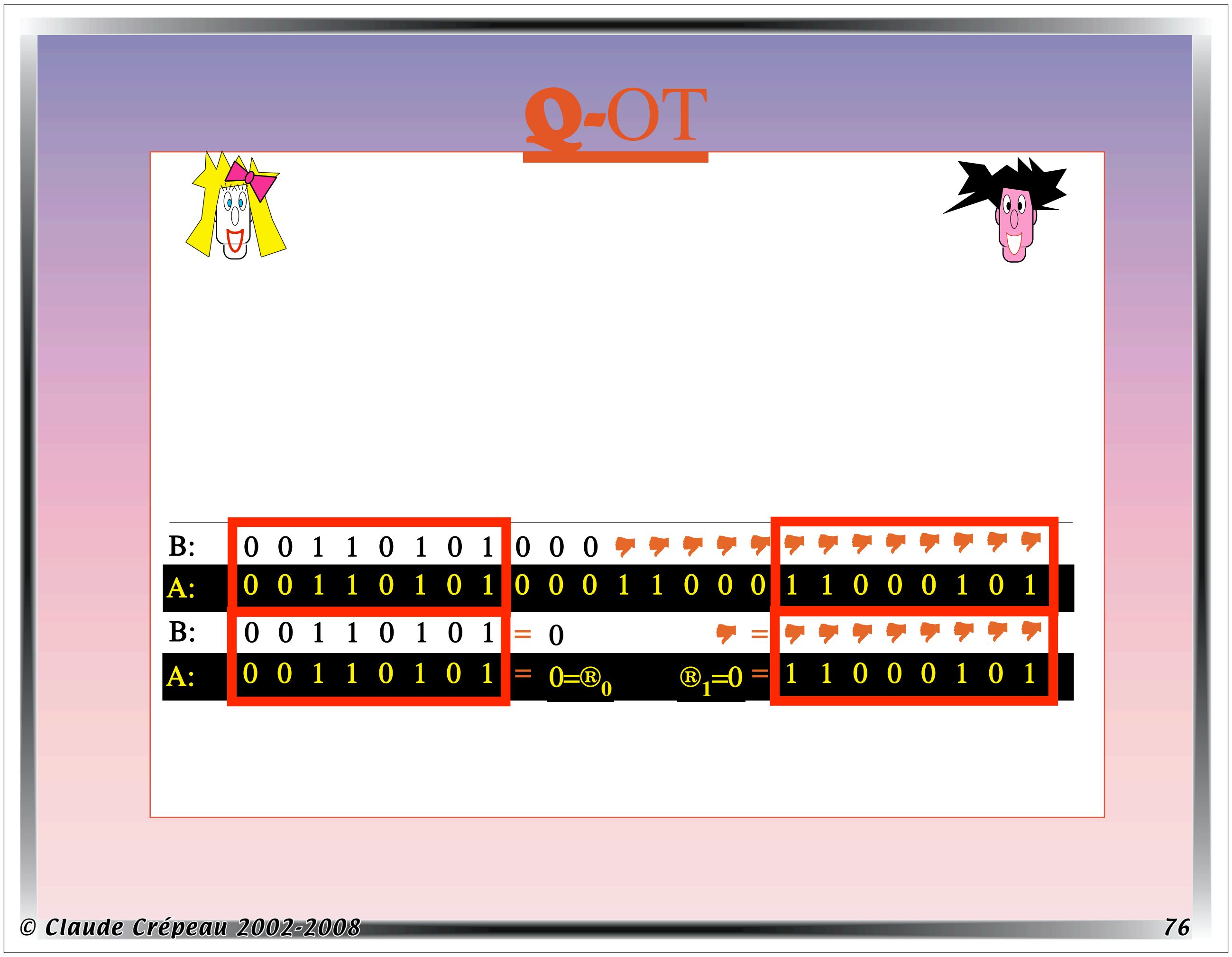


A:	0	1	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	1	0	0	0

B:	0	👎	👎	0	👎	1	👎	👎	1	👎	0	👎	👎	👎	👎	1	0	👎	👎	1	👎	0	0	0
B:	0	0	1	1	0	1	0	1	0	0	0	👎	👎	👎	👎	👎	👎	👎	👎	👎	👎	👎	👎	👎
A:	0	0	1	1	0	1	0	1	0	0	0	1	1	0	0	0	1	1	0	0	0	1	0	1



Oblivious Transfer



Q-OT

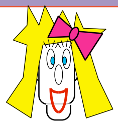
B: 0 0 1 1 0 1 0 1 0 0 0 👎 👎 👎 👎 👎 👎 👎 👎 👎 👎 👎 👎 👎

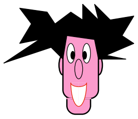
A: 0 0 1 1 0 1 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 1 0 1

B: 0 0 1 1 0 1 0 1 = 0 👎 = 👎 👎 👎 👎 👎 👎 👎 👎

A: 0 0 1 1 0 1 0 1 = 0=®$_0$ ®$_1$=0 = 1 1 0 0 0 1 0 1

Q-OT

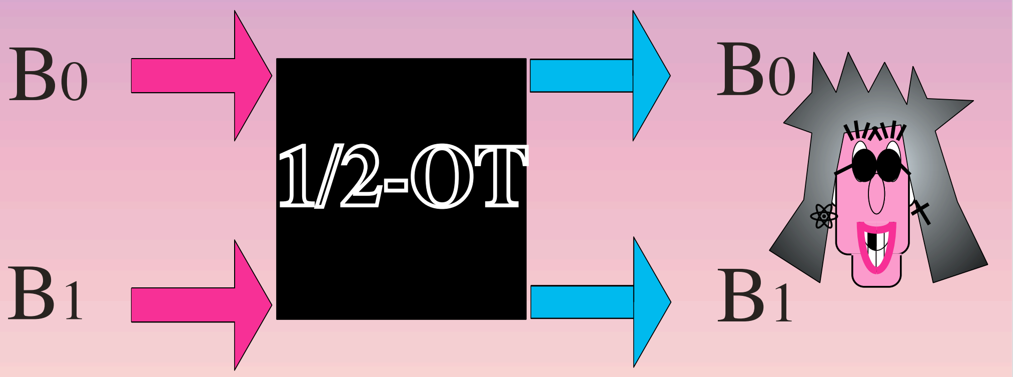


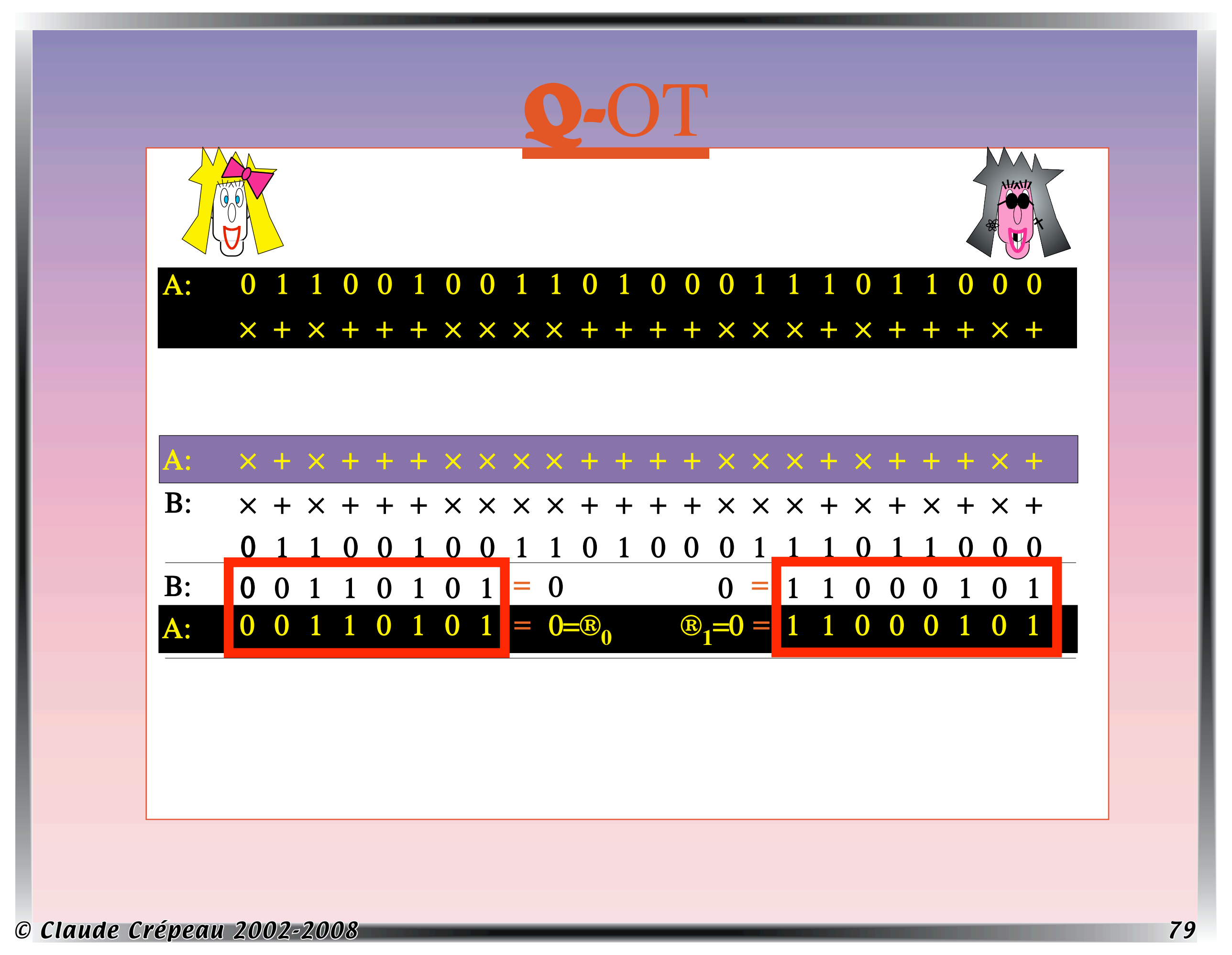


B: 0 0 1 1 0 1 0 1 = 0 👎 = 👎 👎 👎 👎 👎 👎 👎 👎

A: 0 0 1 1 0 1 0 1 = $0=\circledR_0$ $\circledR_1=0$ = 1 1 0 0 0 1 0 1

Oblivious Transfer

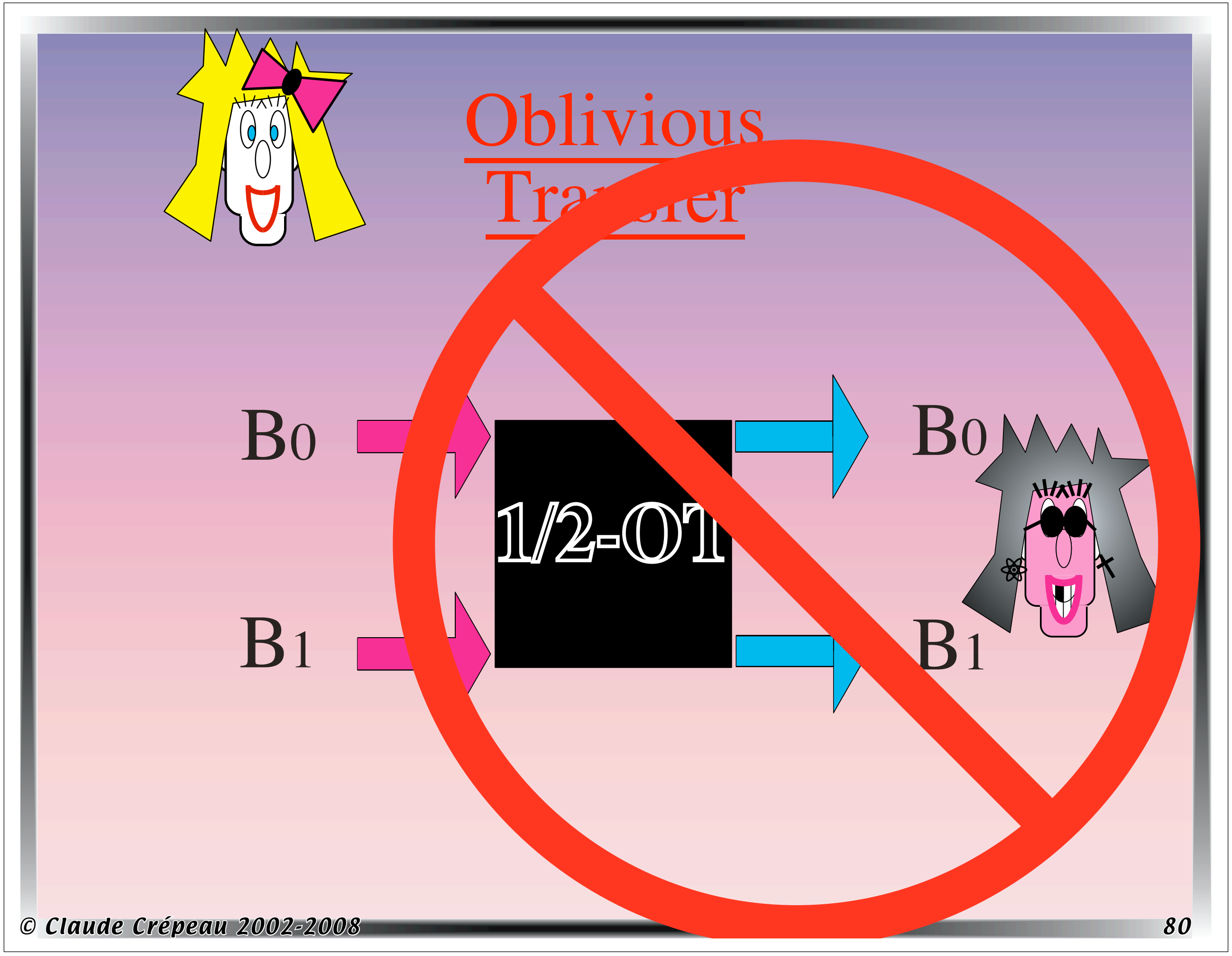




Q-OT

A:	0 1 1 0 0 1 0 0 1 1 0 1 0 0 0 1 1 1 0 1 1 0 0 0
	× + × + + + × × × × + + + + × × × + × + + + × +

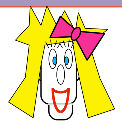
A:	× + × + + + × × × × + + + + × × × + × + + + × +			
B:	× + × + + + × × × × + + + + × × × + × + × + × +			
	0 1 1 0 0 1 0 0 1 1 0 1 0 0 0 1 1 1 0 1 1 0 0 0			
B:	0 0 1 1 0 1 0 1	= 0	0 =	1 1 0 0 0 1 0 1
A:	0 0 1 1 0 1 0 1	= 0=®$_0$	®$_1$=0 =	1 1 0 0 0 1 0 1



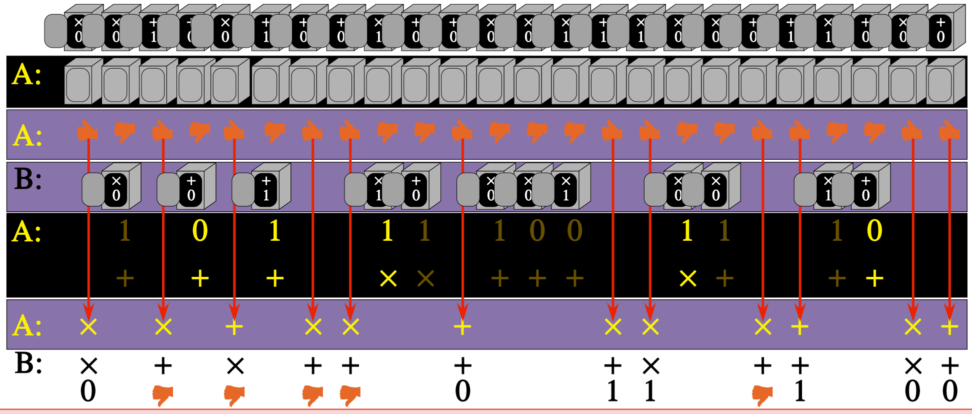
Oblivious Transfer

Q-OT

from Q-BC

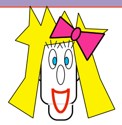


A:	0	1	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	1	0	0	0
	×	+	×	+	+	+	×	×	×	×	+	+	+	+	×	×	×	+	×	+	+	+	×	+
B:	×	×	+	+	×	+	+	+	×	+	+	×	×	×	+	×	×	×	+	+	×	+	×	+
	0	0	1	0	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0

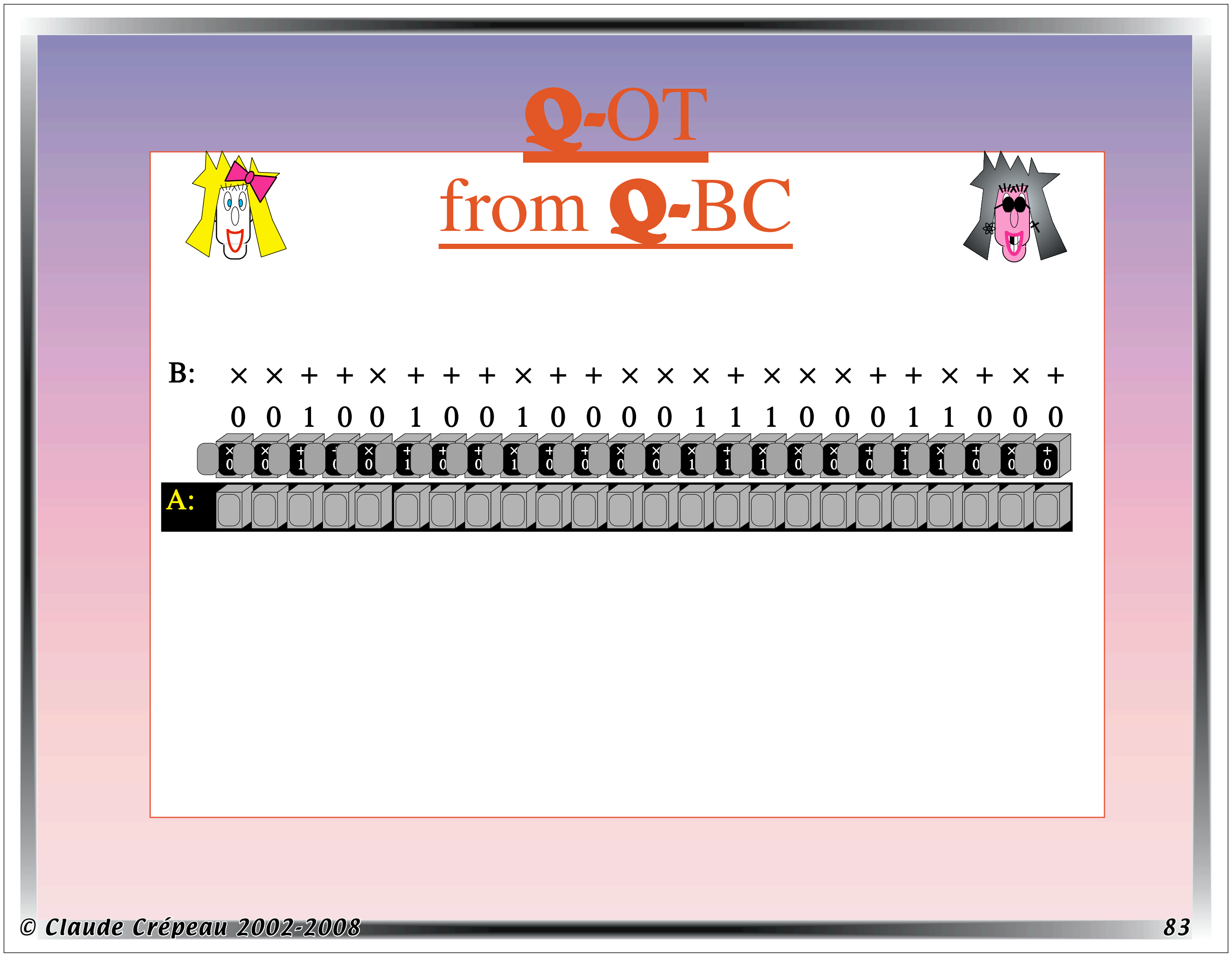

A:
A:
B:
A: 1 0 1 1 1 1 0 0 1 1 1 0
+ + + × × + + + × + + +
A: × × + × × + × × × + × +
B: × + × + + + + × + + × +
0 0 1 1 1 0 0

Q-OT

from Q-BC



A:	0	1	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	1	0	0	0
	×	+	×	+	+	+	×	×	×	×	+	+	+	+	×	×	×	+	×	+	+	+	×	+
B:	×	×	+	+	×	+	+	+	×	+	+	×	×	×	+	×	×	×	+	+	×	+	×	+
	0	0	1	0	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0

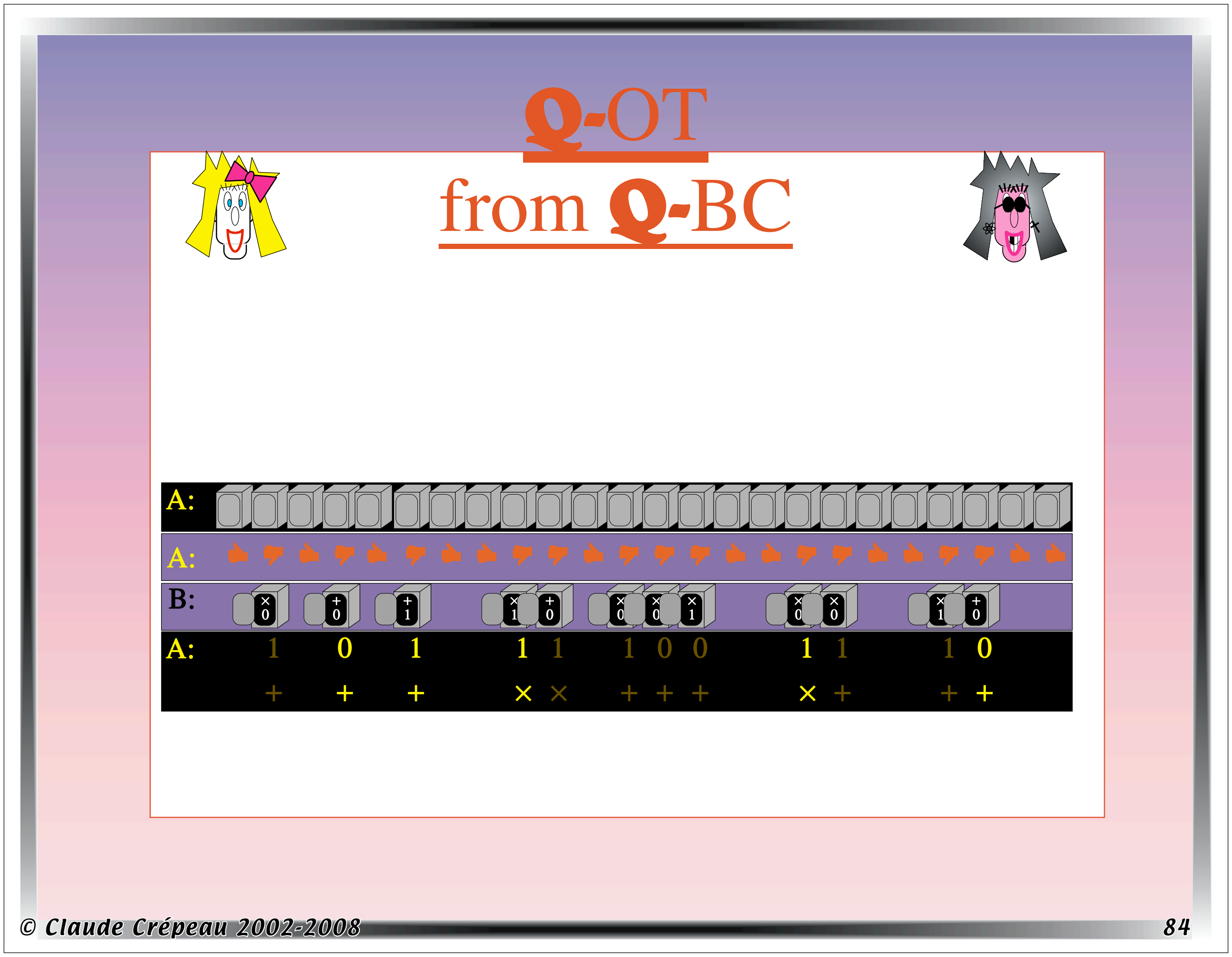


Q-OT from Q-BC

B: × × + + × + + + × + + × × × + × × × + + × + × +

0 0 1 0 0 1 0 0 1 0 0 0 0 1 1 1 0 0 0 1 1 0 0 0

A:



Q-OT from Q-BC

A:

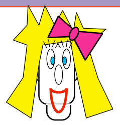
A:

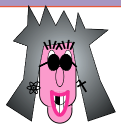
B:

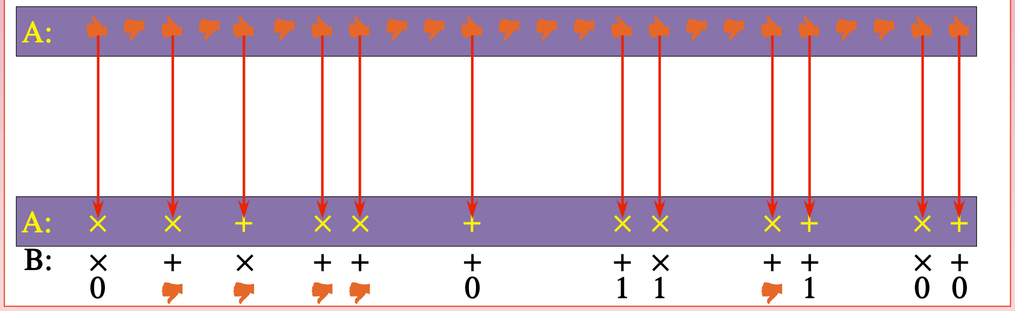
A: 1 0 1 1 1 1 0 0 1 1 1 0

+ + + × × + + + × + + +

Q-OT
from Q-BC

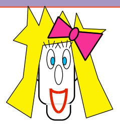


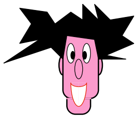




A:	👍	👎	👍	👎	👍	👎	👍	👍	👎	👎	👍	👎	👎	👎	👍	👍	👎	👎	👍	👍	👎	👎	👍	👍
A:	×		×		+		×	×			+				×	×			×	+			×	+
B:	×		+		×		+	+			+				+	×			+	+			×	+
	0		👎		👎		👎	👎			0				1	1			👎	1			0	0

Q-OT





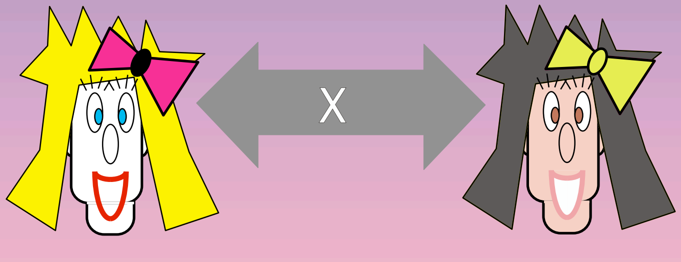
A:	0	1	1	0	0	1	0	0	1	1	0	1	0	0	0	1	1	1	0	1	1	0	0	0
	×	+	×	+	+	+	×	×	×	×	+	+	+	+	×	×	×	+	×	+	+	+	×	+
B:	×	×	+	+	×	+	+	+	×	+	+	×	×	×	+	×	×	×	+	+	×	+	×	+
	0	0	1	0	0	1	0	0	1	0	0	0	0	1	1	1	0	0	0	1	1	0	0	0
A:	×	+	×	+	+	+	×	×	×	×	+	+	+	+	×	×	×	+	×	+	+	+	×	+
B:	0	👎	👎	0	👎	1	👎	👎	1	👎	0	👎	👎	👎	👎	1	0	👎	👎	1	👎	0	0	0

(6)
two provers
Cryptographic Protocols

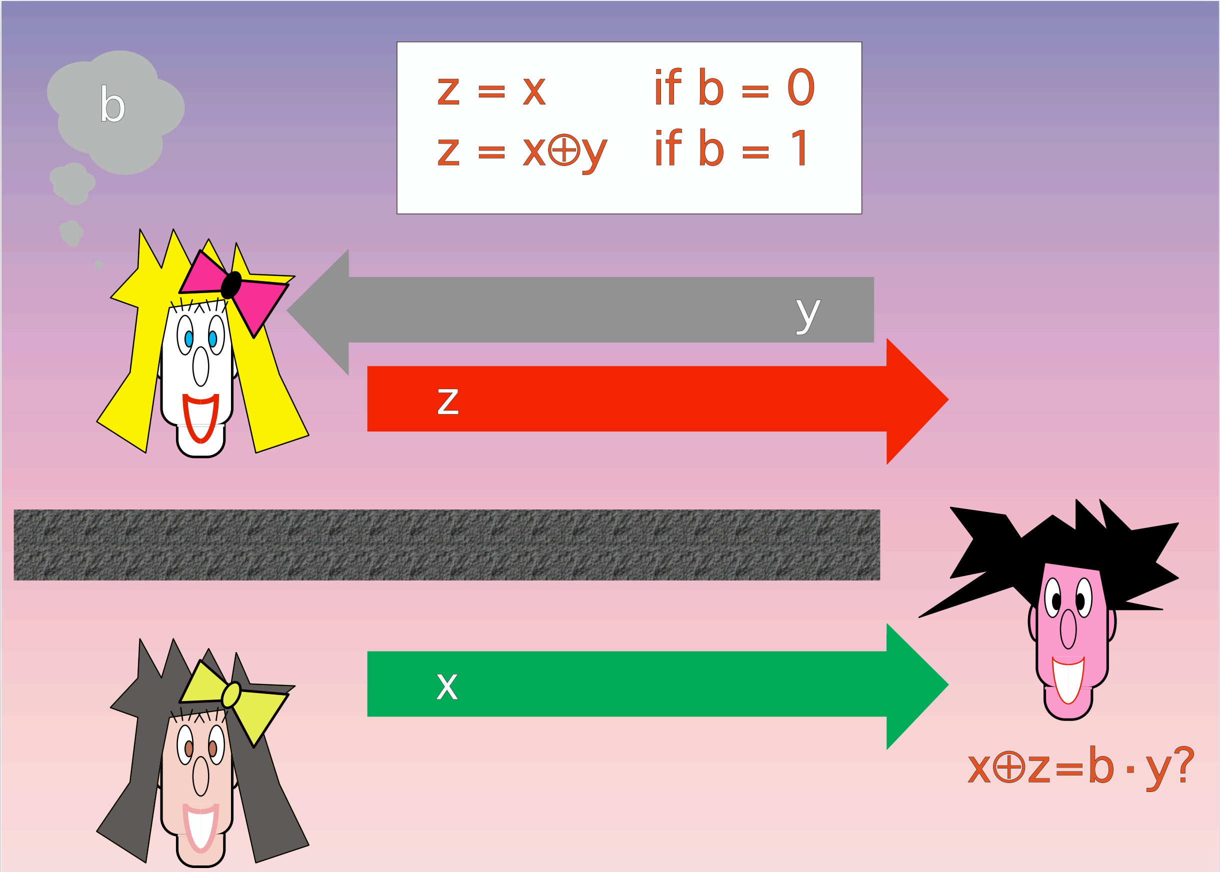
Classically

BGKW88

Classically



Ben-Or, Goldwasser, Kilian, Wigderson

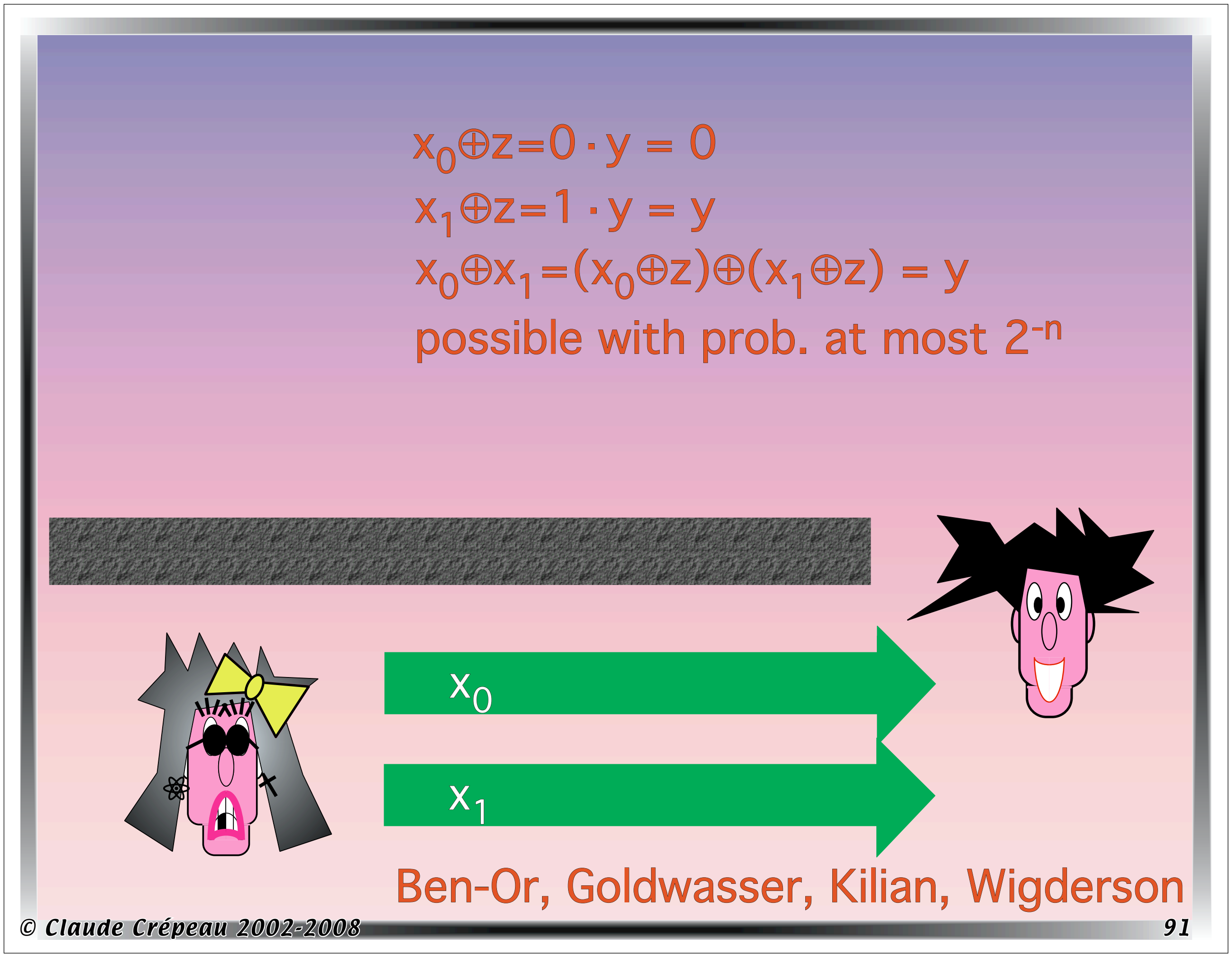


$z = x$ if $b = 0$

$z = x \oplus y$ if $b = 1$

$x \oplus z = b \cdot y$?

Ben-Or, Goldwasser, Kilian, Wigderson



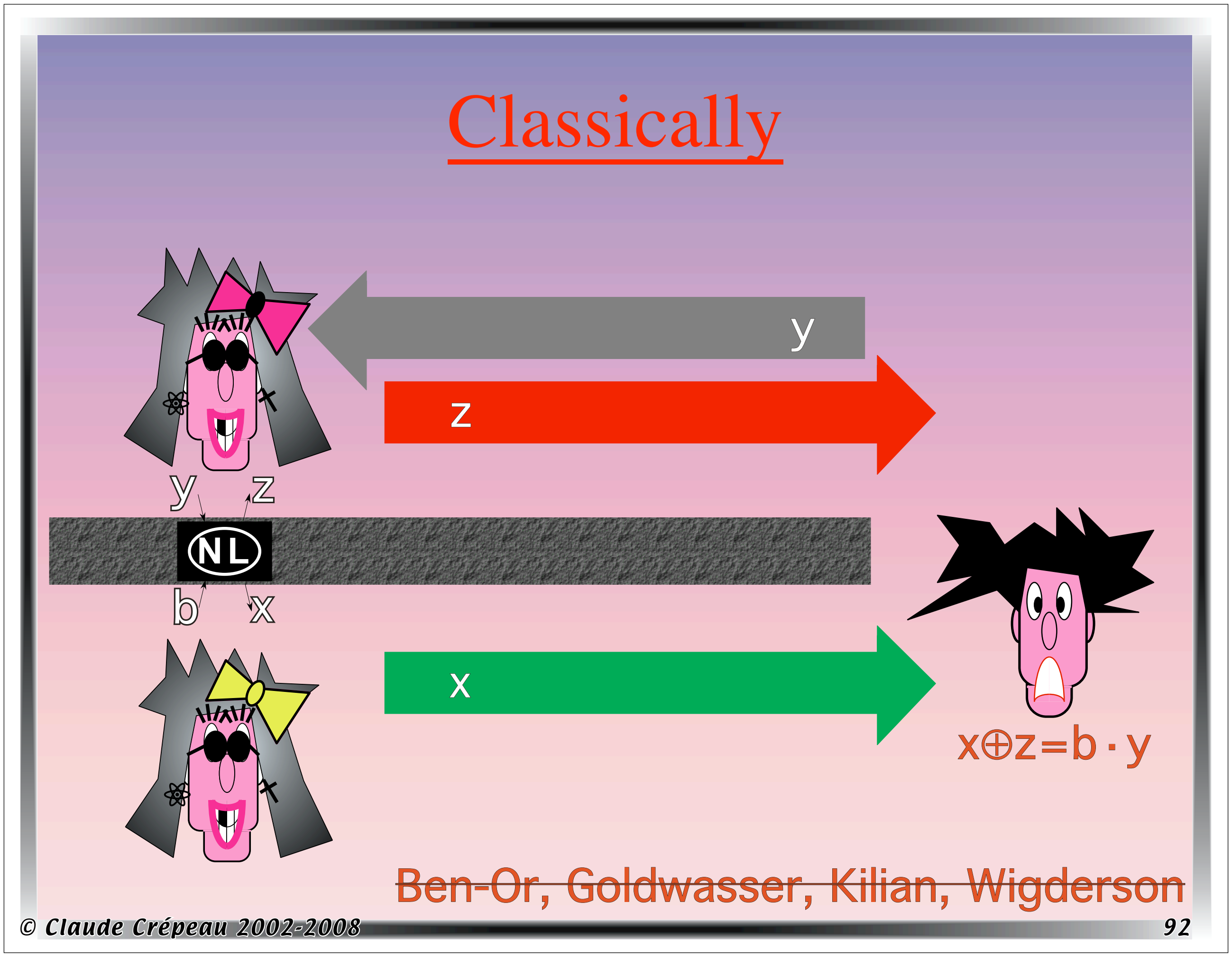
$x_0 \oplus z = 0 \cdot y = 0$

$x_1 \oplus z = 1 \cdot y = y$

$x_0 \oplus x_1 = (x_0 \oplus z) \oplus (x_1 \oplus z) = y$

possible with prob. at most 2^{-n}

Ben-Or, Goldwasser, Kilian, Wigderson

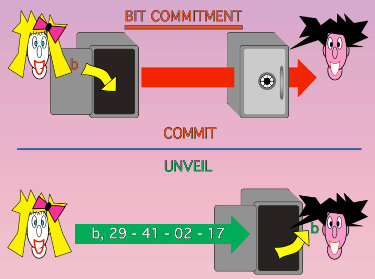


Classically

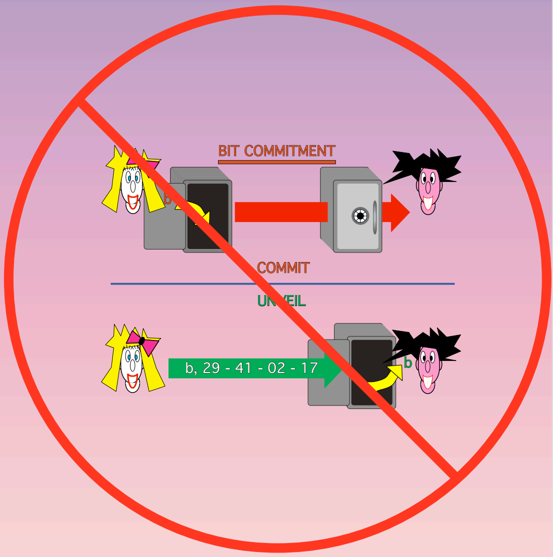
$x \oplus z = b \cdot y$

~~Ben-Or, Goldwasser, Kilian, Wigderson~~

Quantumly

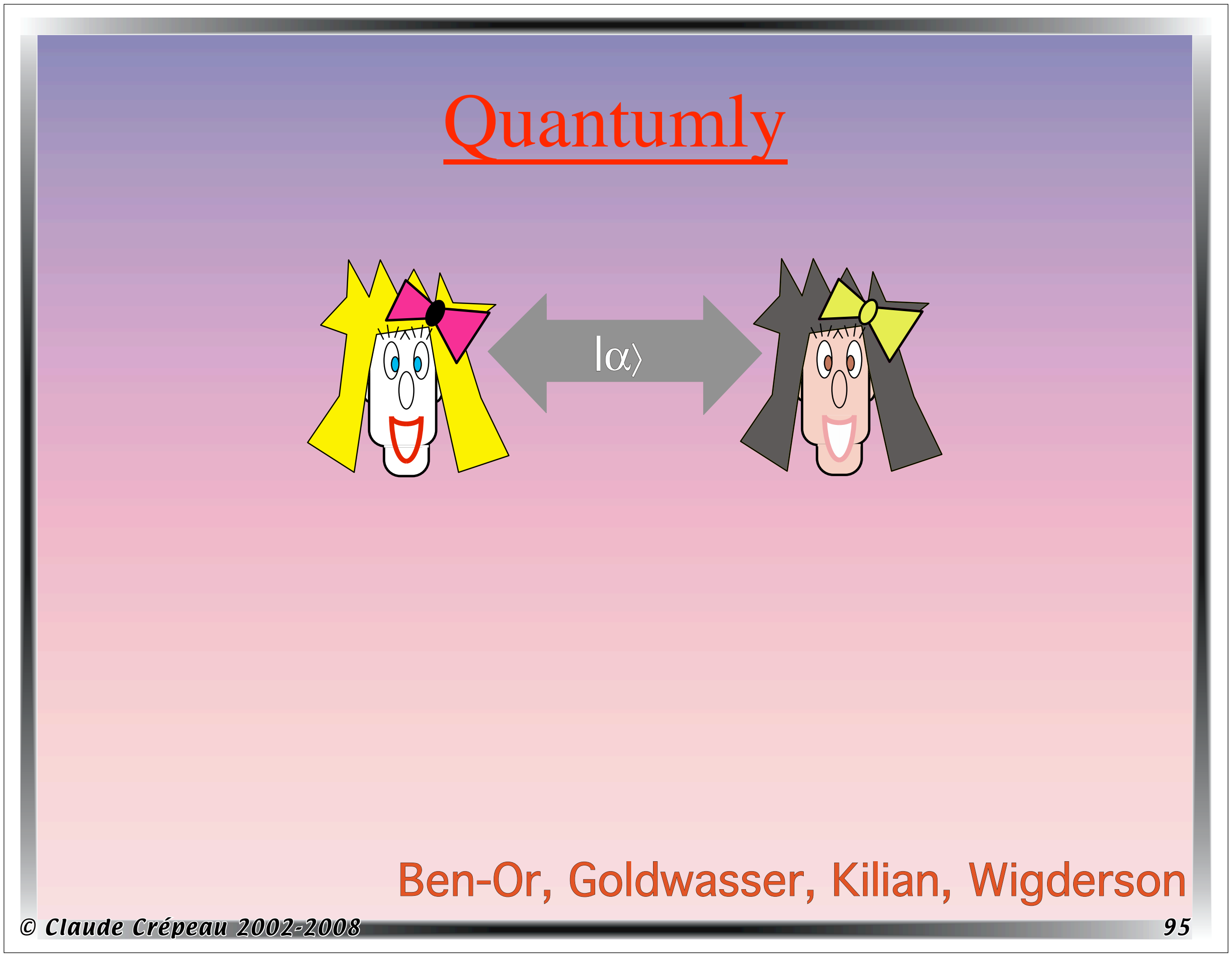


or



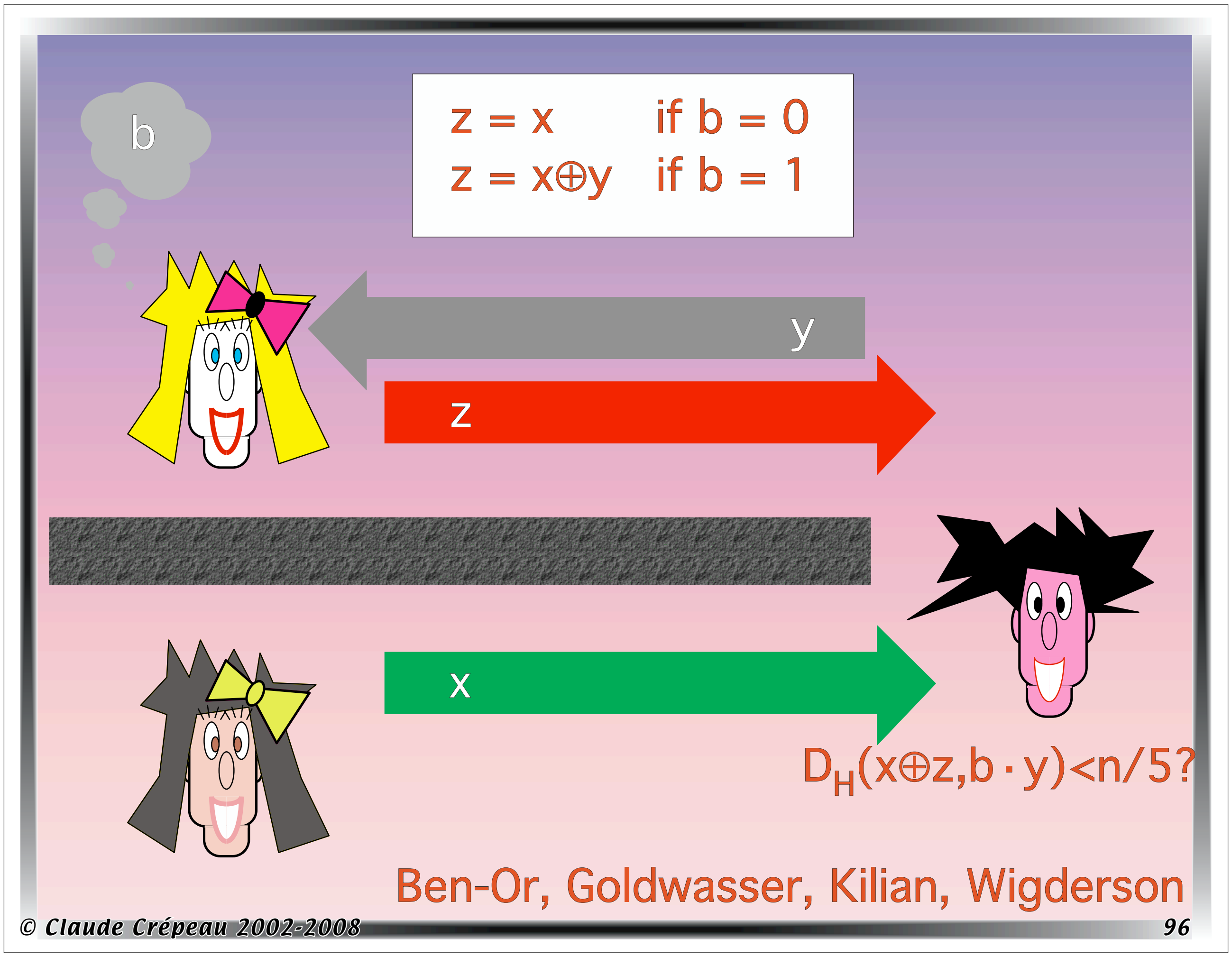
???

(7)
two provers BC
Classically Secure
Quantumly Insecure



Quantumly

Ben-Or, Goldwasser, Kilian, Wigderson

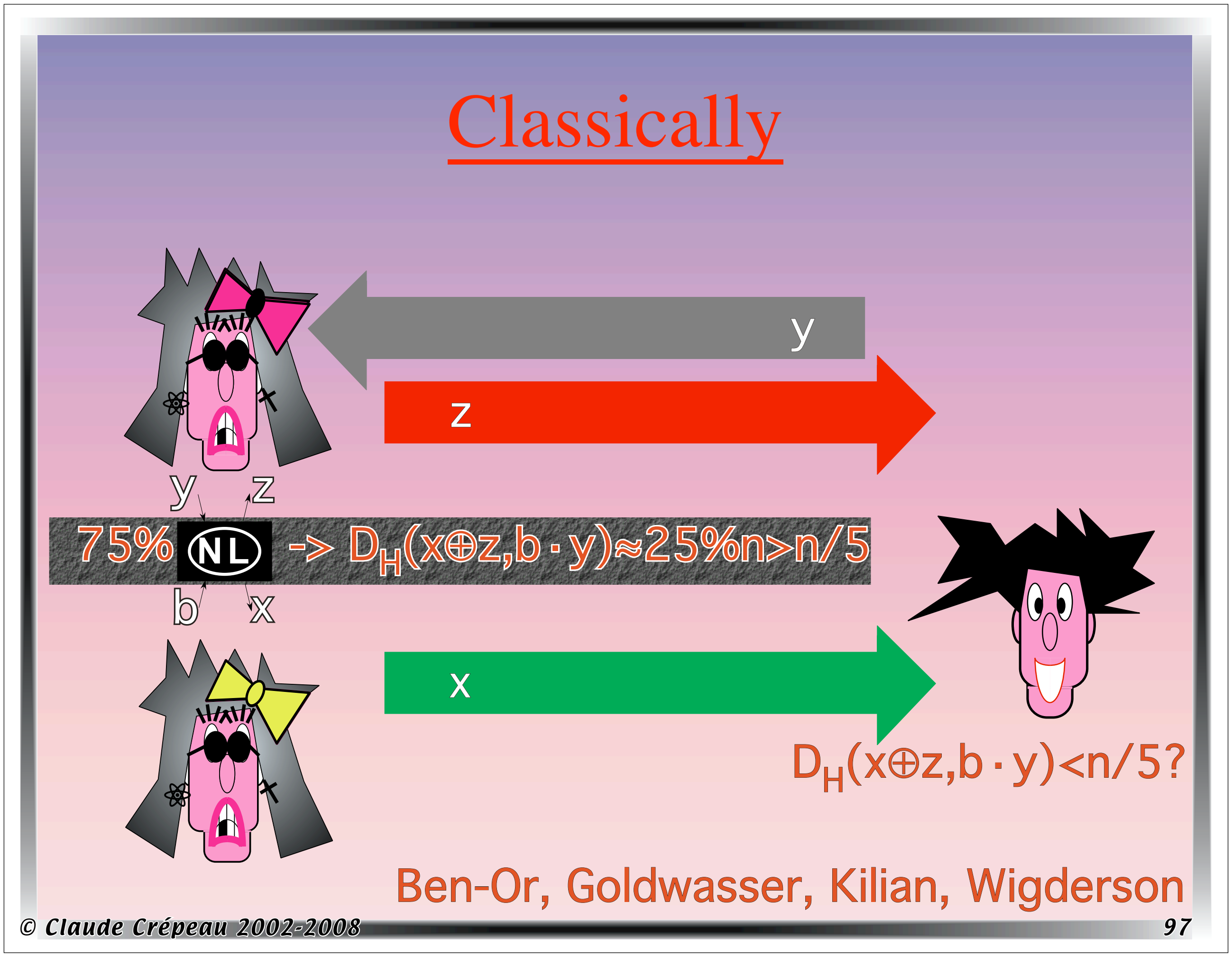


$z = x$ if $b = 0$

$z = x \oplus y$ if $b = 1$

$D_H(x \oplus z, b \cdot y) < n/5?$

Ben-Or, Goldwasser, Kilian, Wigderson

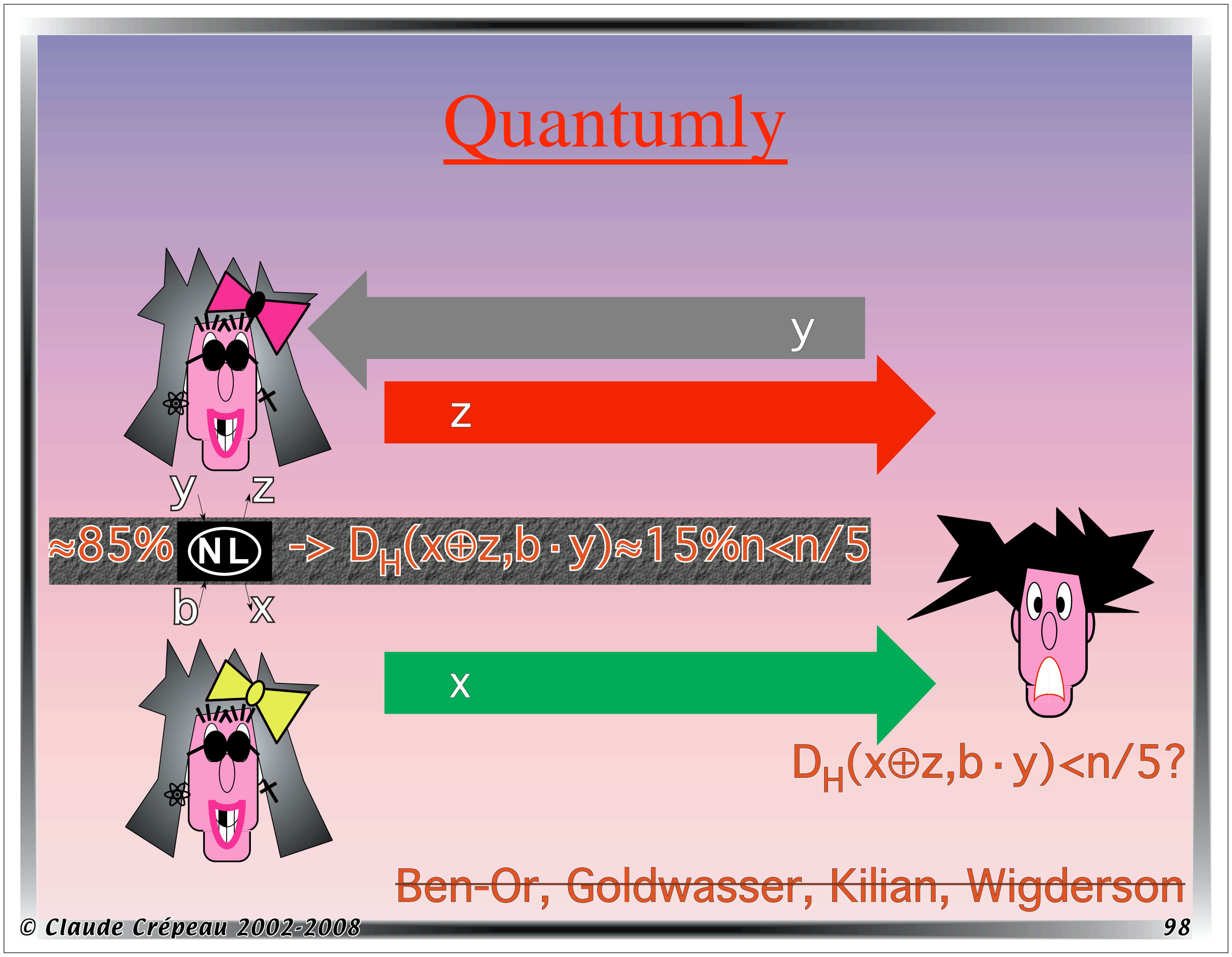


Classically

75% NL -> $D_H(x\oplus z,b\cdot y)\approx 25\%n>n/5$

$D_H(x\oplus z,b\cdot y)<n/5$?

Ben-Or, Goldwasser, Kilian, Wigderson



Quantumly

≈85% NL -> $D_H(x\oplus z,b\cdot y)\approx 15\%n<n/5$

$D_H(x\oplus z,b\cdot y)<n/5$?

~~Ben-Or, Goldwasser, Kilian, Wigderson~~

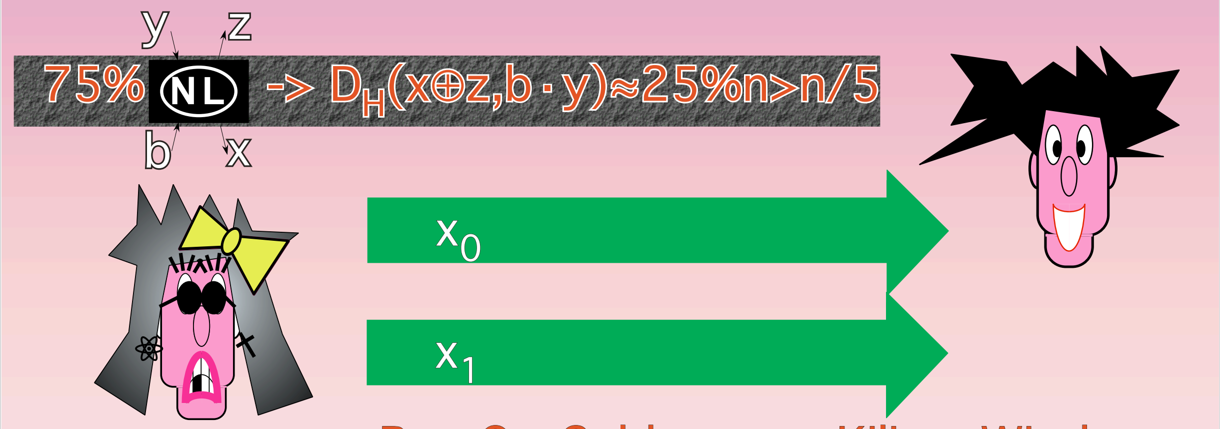
Classically

$D_H(x_0 \oplus z, 0 \cdot y) = D_H(x_0 \oplus z, 0) < n/5$

$D_H(x_1 \oplus z, 1 \cdot y) = D_H(x_1 \oplus z, y) < n/5$

$D_H(x_0 \oplus x_1, y) = D_H((x_0 \oplus z) \oplus (x_1 \oplus z), y) < 2n/5 < n/2$

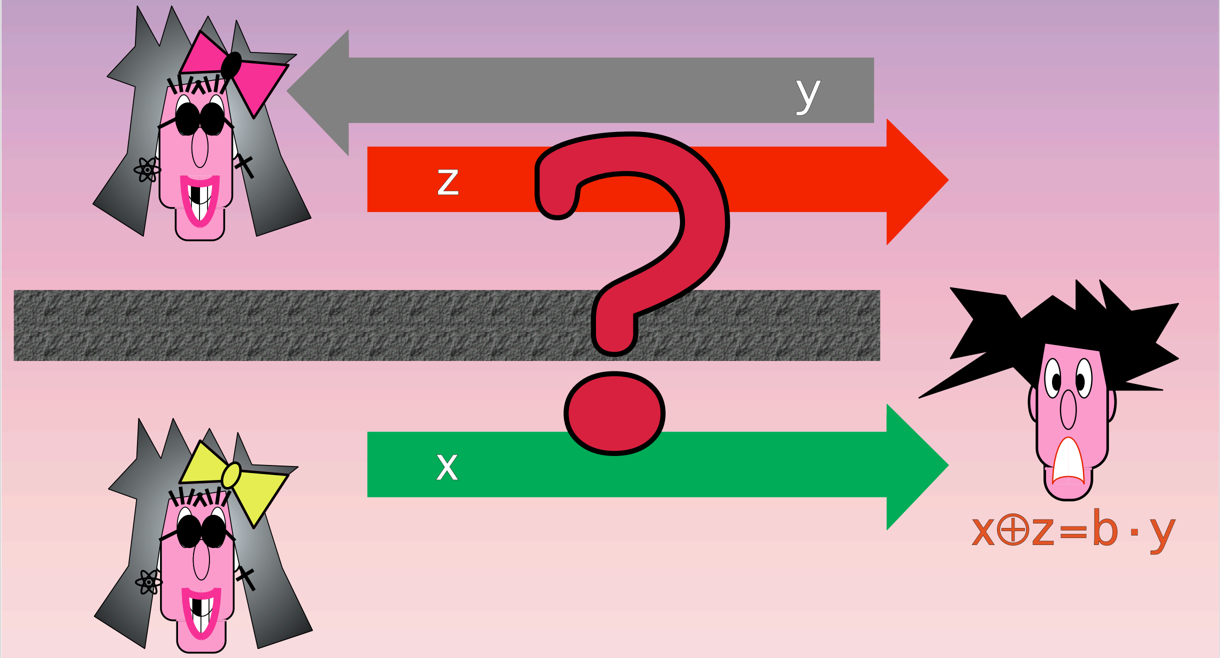
possible with prob. at most c^{-n}



75% NL -> $D_H(x \oplus z, b \cdot y) \approx 25\% n > n/5$

Ben-Or, Goldwasser, Kilian, Wigderson

Quantumly

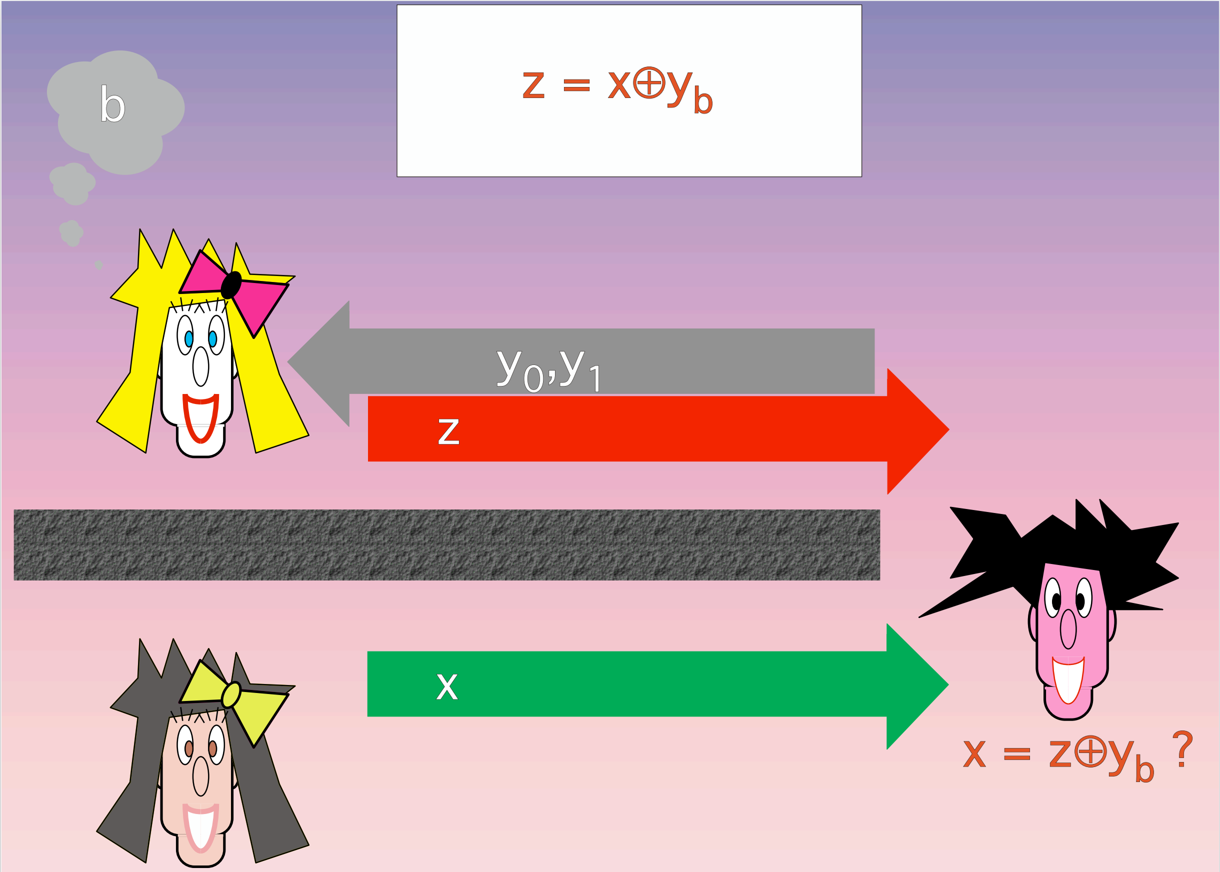


$x \oplus z = b \cdot y$

~~Ben-Or, Goldwasser, Kilian, Wigderson~~

(8) two provers BC Classically and Quantumly Secure

$z = x \oplus y_b$



modified BGKW

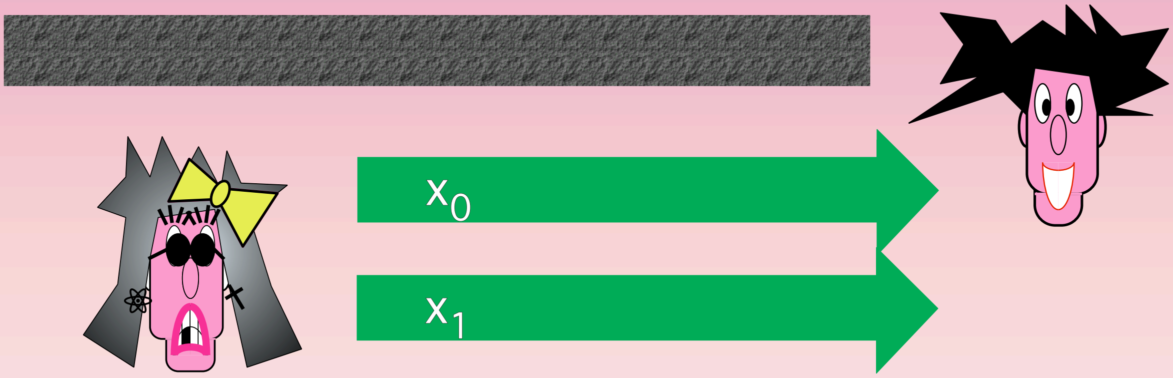
Classically

$x_0 \oplus z = y_0$

$x_1 \oplus z = y_1$

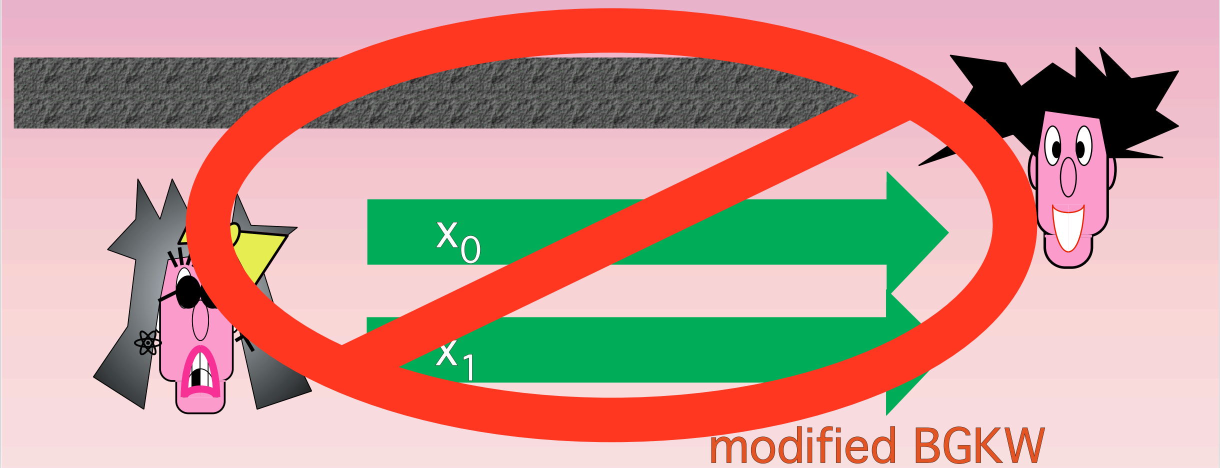
$x_0 \oplus x_1 = (x_0 \oplus z) \oplus (x_1 \oplus z) = y_0 \oplus y_1$

possible with prob. at most 2^{-n}



modified BGKW

Quantumly



modified BGKW

Quantumly

MAIN THEOREM

Let 0 and 1 be POVMs such that outputs x_0 and x_1 one could obtain by applying one of them to the state shared among the two provers.

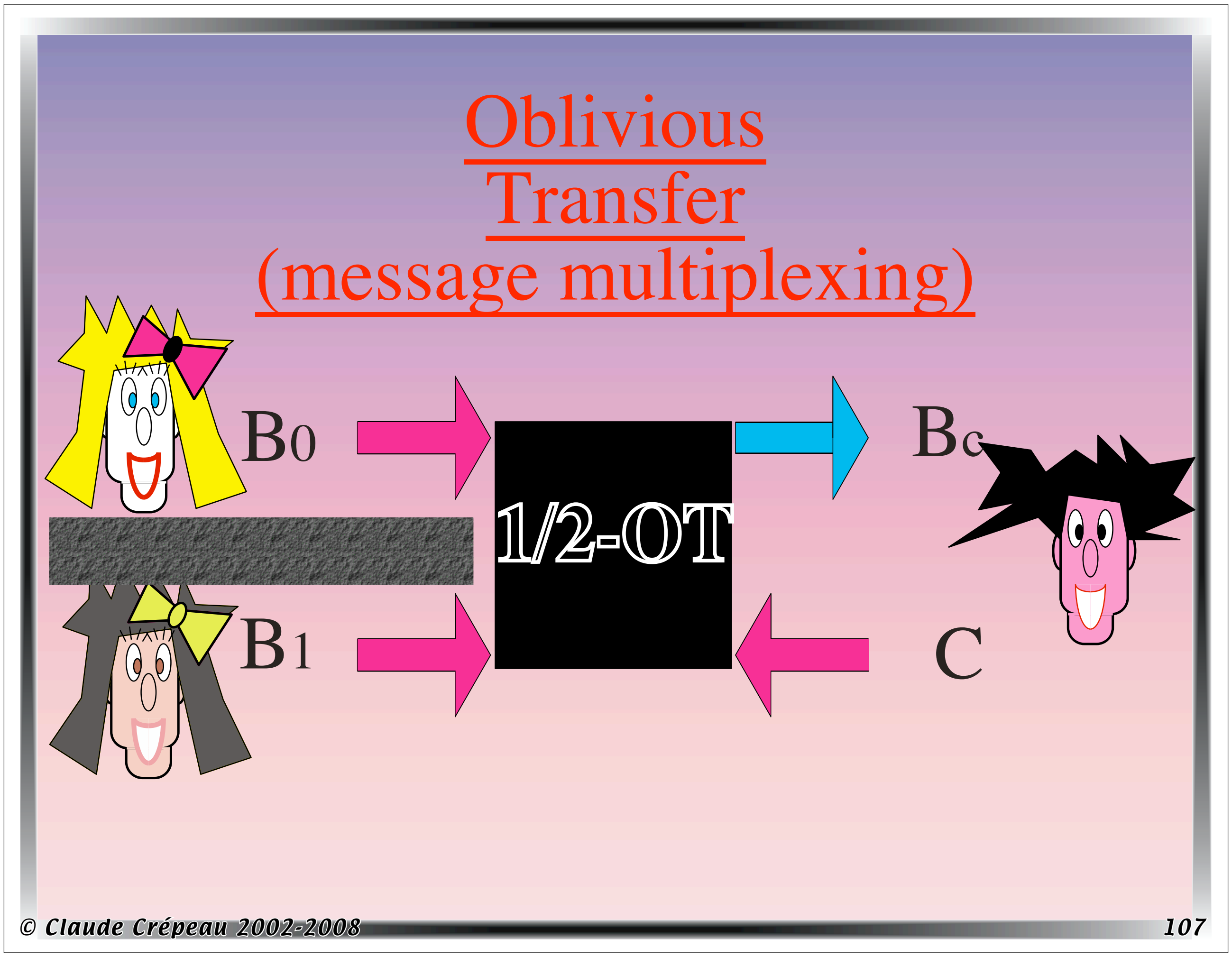
Suppose the success probability of unveiling is

$$p_0+p_1 > 1+\delta,$$

then the (prediction probability of $y_0 \oplus y_1$) > δ.

This prediction probability is achieved by first applying 0 to the shared state followed by 1 on the leftover system or the other way around.

(9)
WARNING !



Oblivious Transfer (message multiplexing)

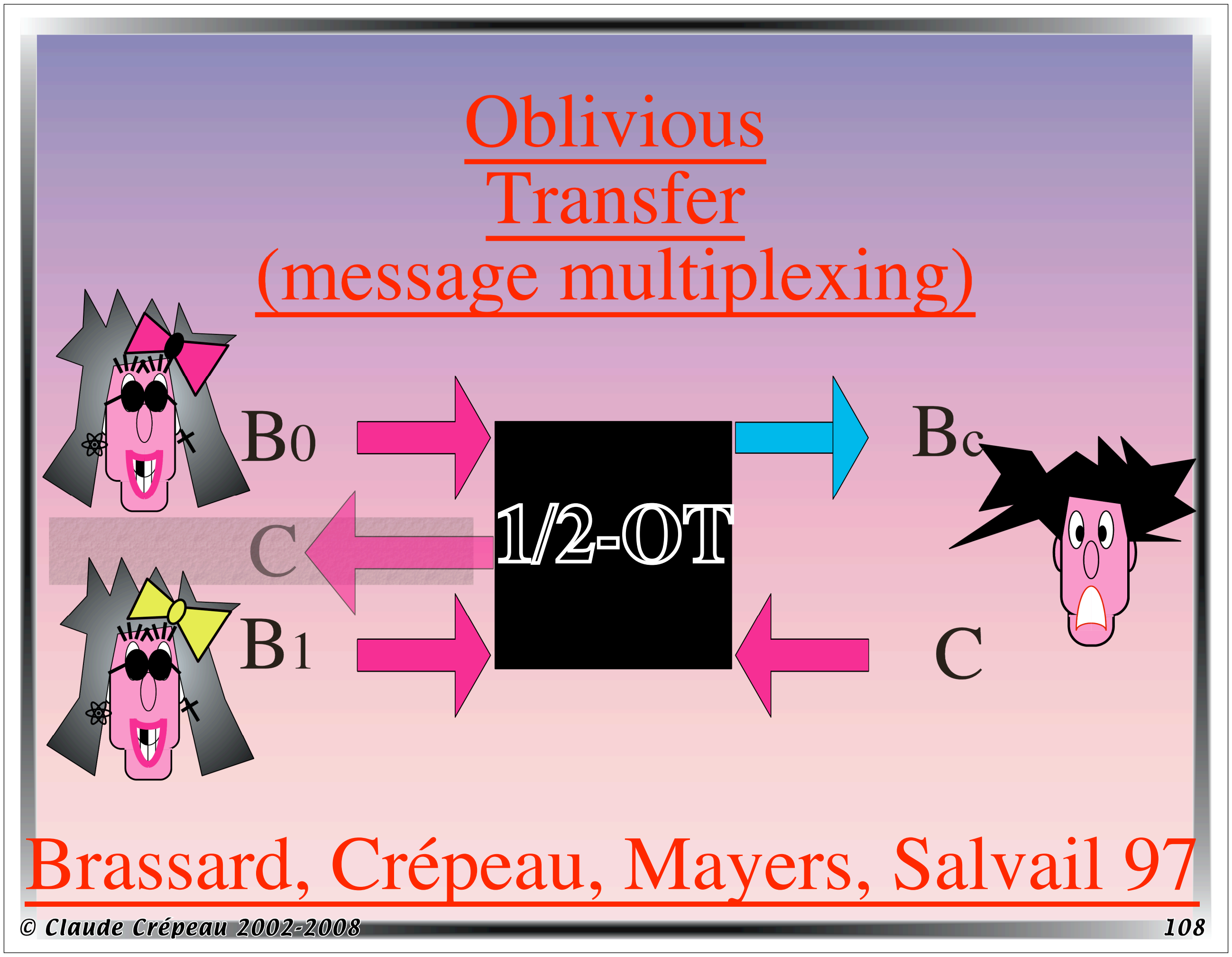
B_0

B_1

1/2-OT

B_c

C



Oblivious Transfer (message multiplexing)

B_0

C

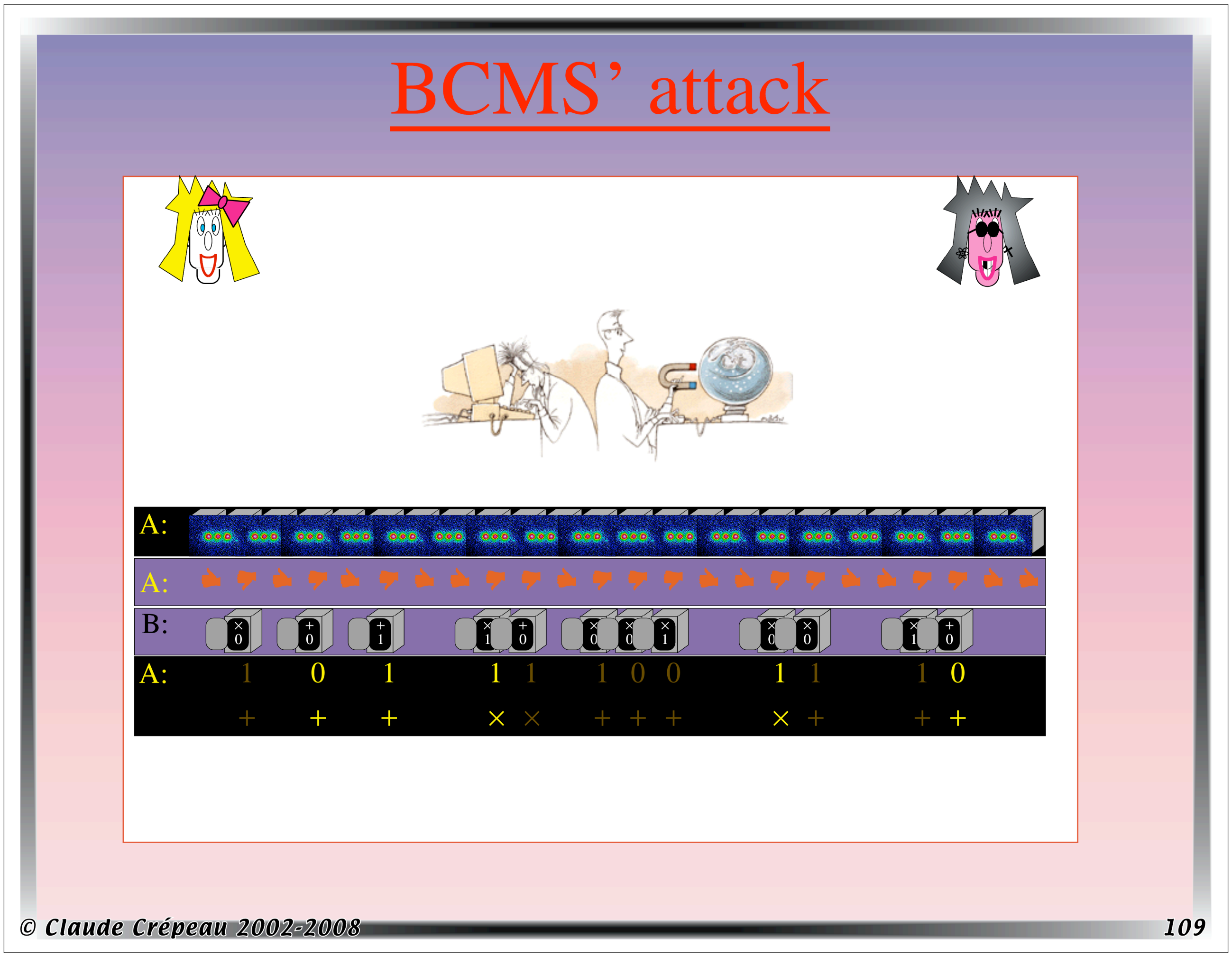
B_1

1/2-OT

B_c

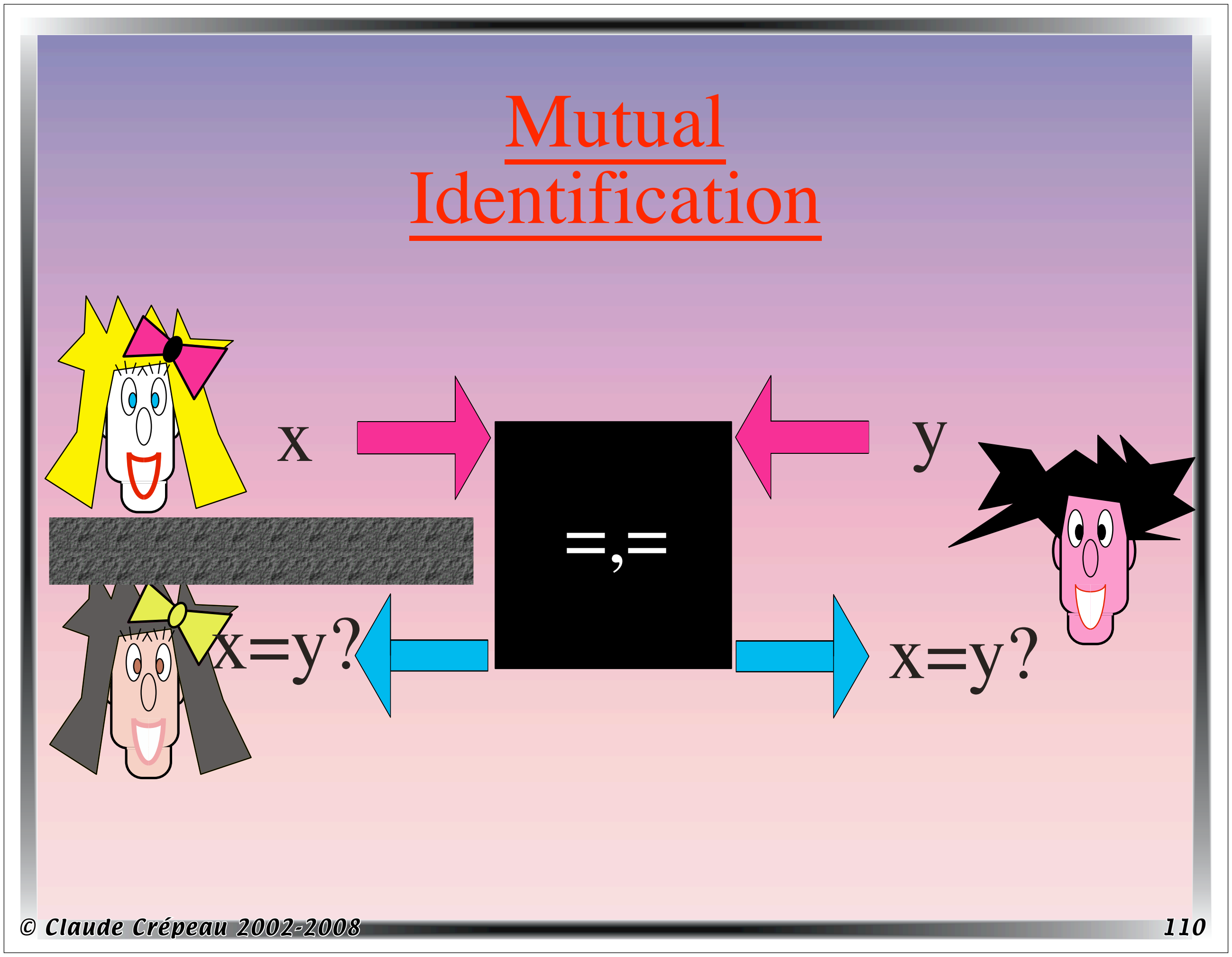
C

Brassard, Crépeau, Mayers, Salvail 97



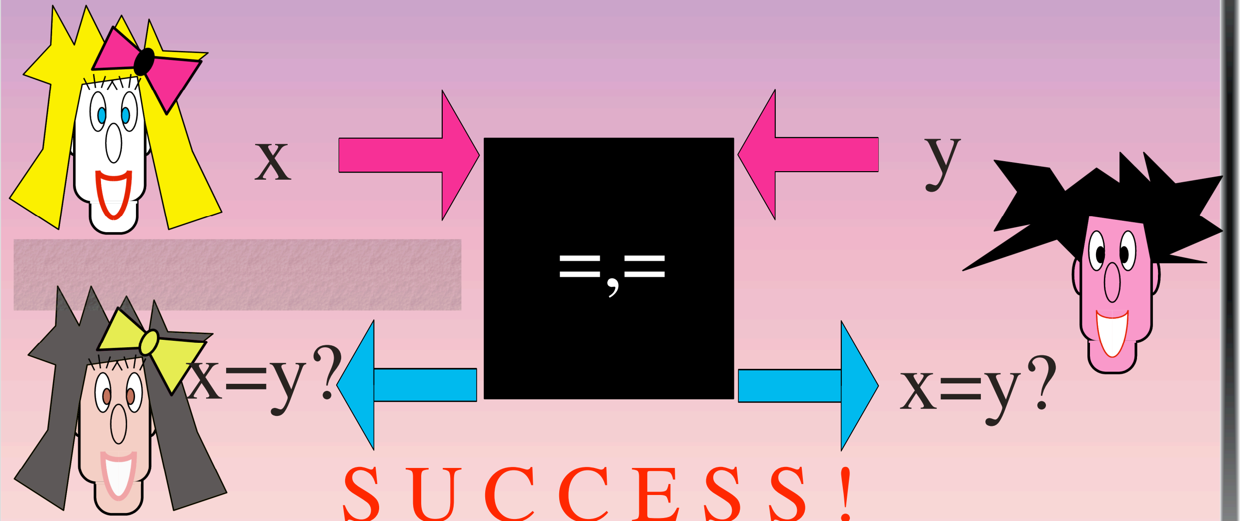
BCMS' attack

A:
A:
B: ×0 +0 +1 ×1 +0 ×0 ×0 ×1 ×0 ×0 ×1 +0
A: 1 0 1 1 1 1 0 0 1 1 1 0
+ + + × × + + + × + + +



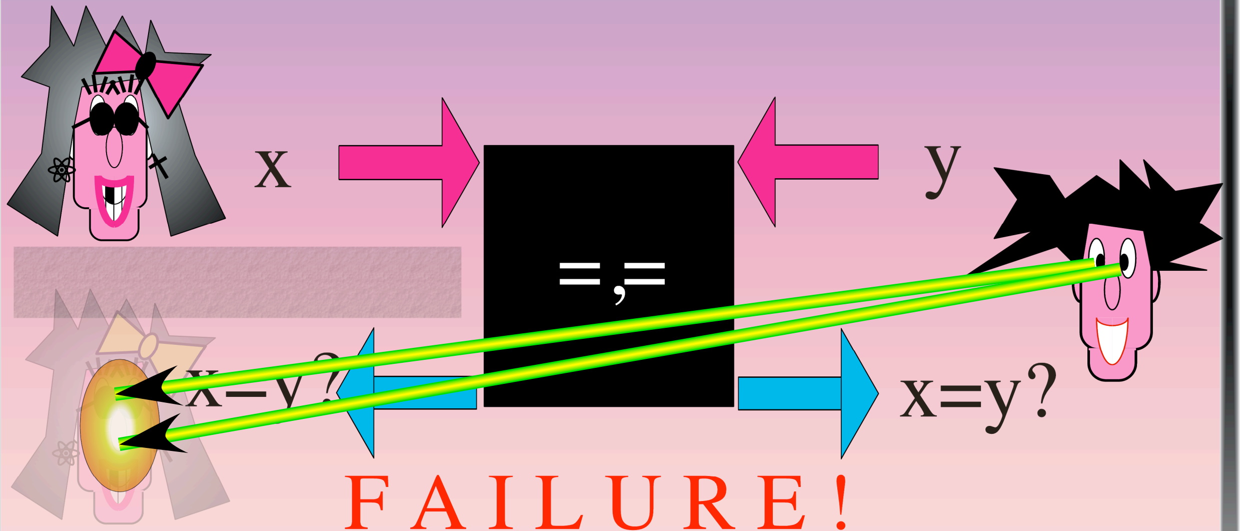
Mutual Identification

Mutual Identification

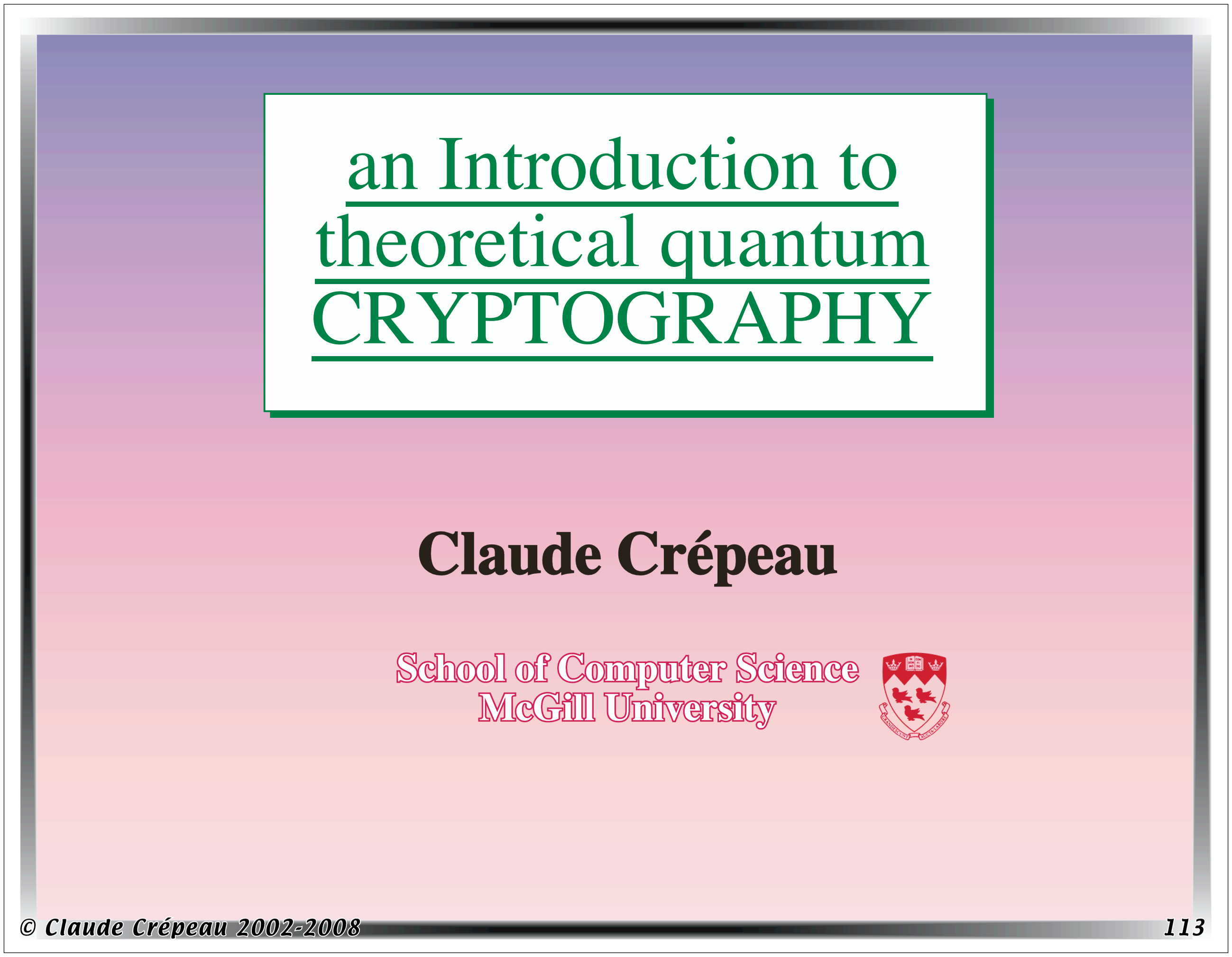


SUCCESS!

Mutual Identification



FAILURE!



an Introduction to theoretical quantum CRYPTOGRAPHY

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