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Explicit asymptotic secret key rate of continuous-variable QKD with an arbitrary modulation

Quantum 5, 540 (2021)

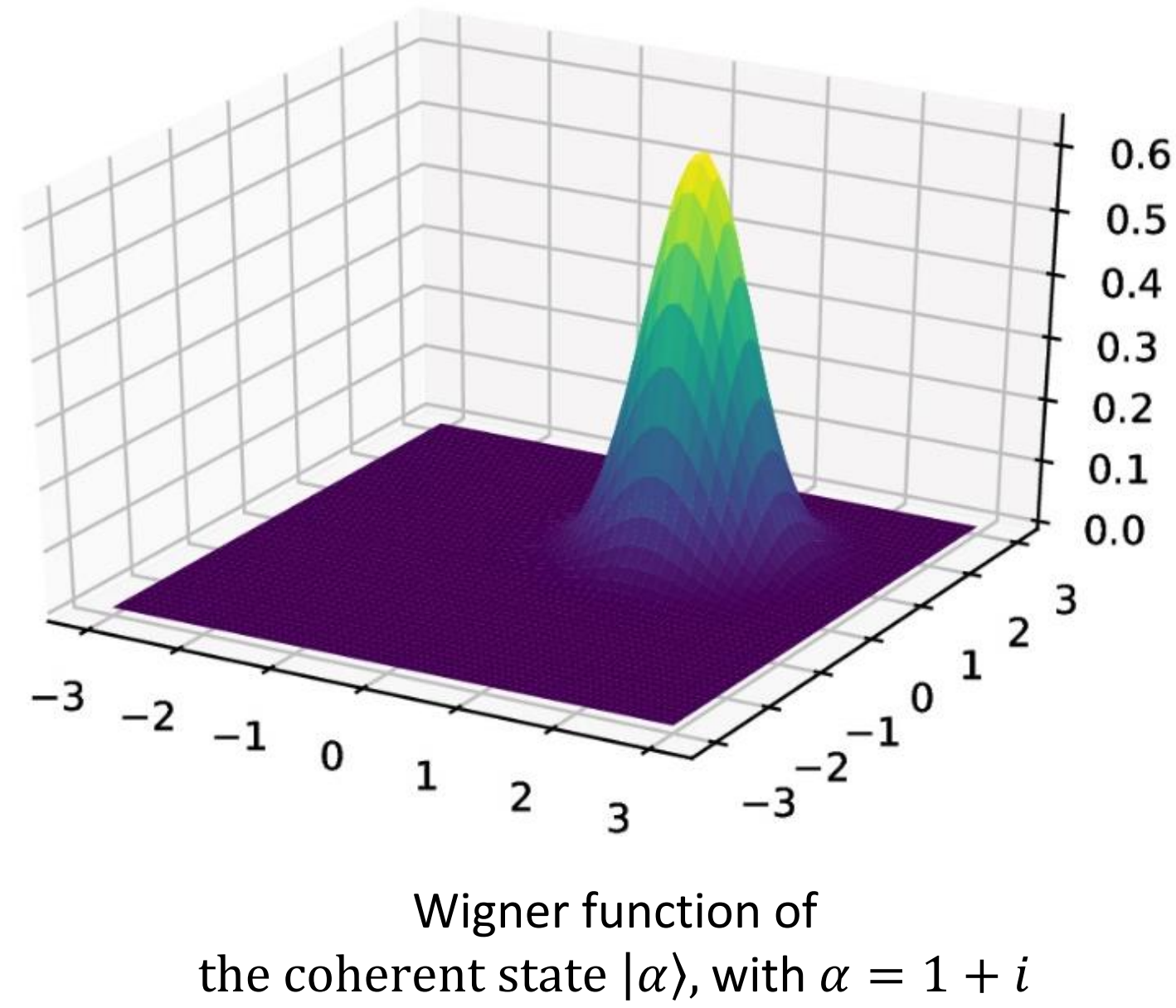
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CONTINUOUS VARIABLE QKD PROTOCOL

Quantum part (repeated):

1. Alice randomly chooses one coherent state $|\alpha_k\rangle$ with probability p_k from a set of coherent states $\{|\alpha_k\rangle\}_{k \in I}$ and sends it to Bob.
2. Bob measures the quadratures of the states he receives, using coherent detection, and obtains β_k .



+ Classical post-processing

SECURITY PROOF

Security proof in the asymptotic regime, under the restriction to collective attacks

Main steps:

Devetak-Winter bound : bound on the asymptotic secret key rate

$$k = I(X; Y) - \sup_{N: A' \rightarrow B} \chi(Y; E)$$

Function of a covariance matrix :

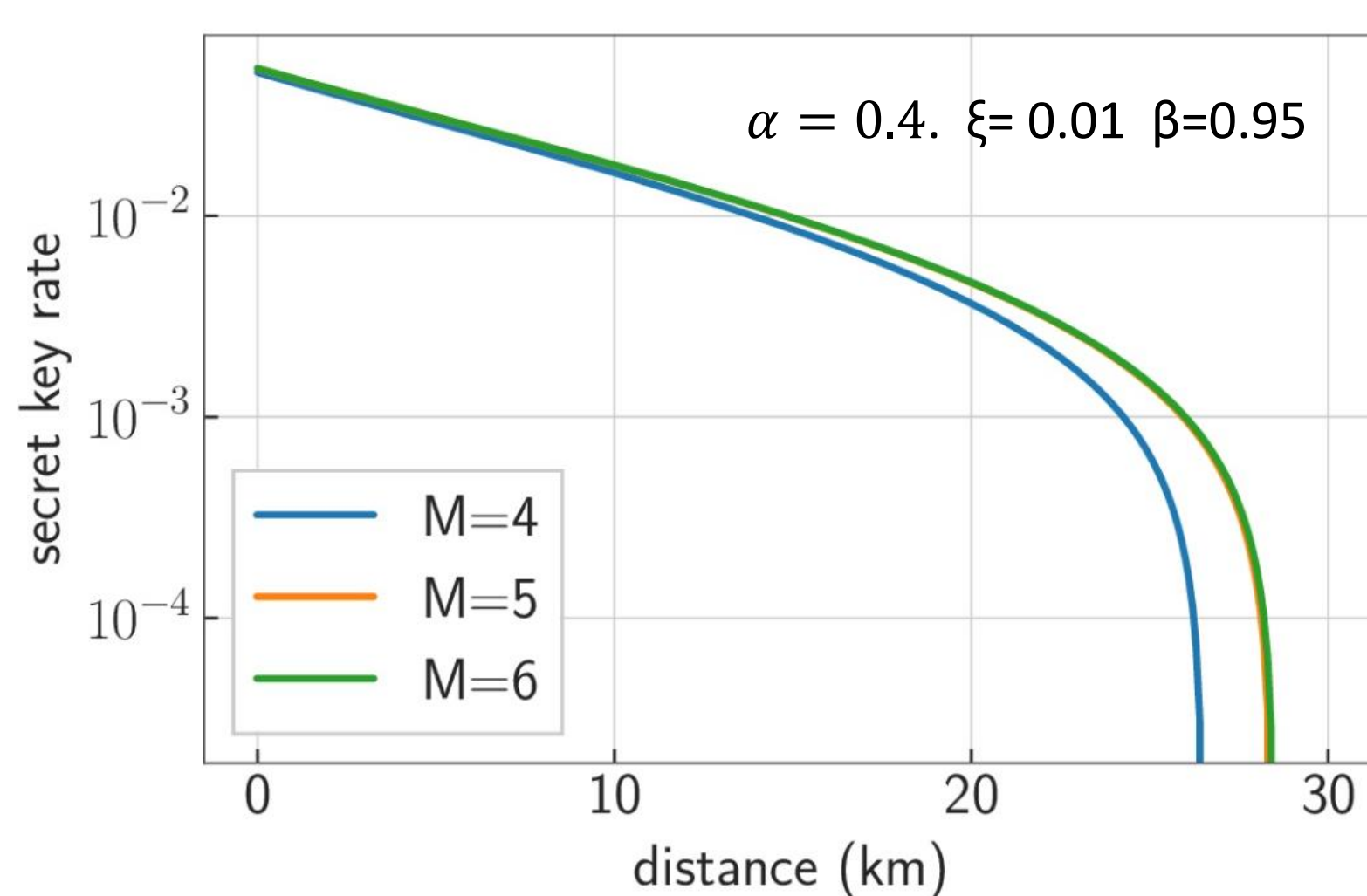
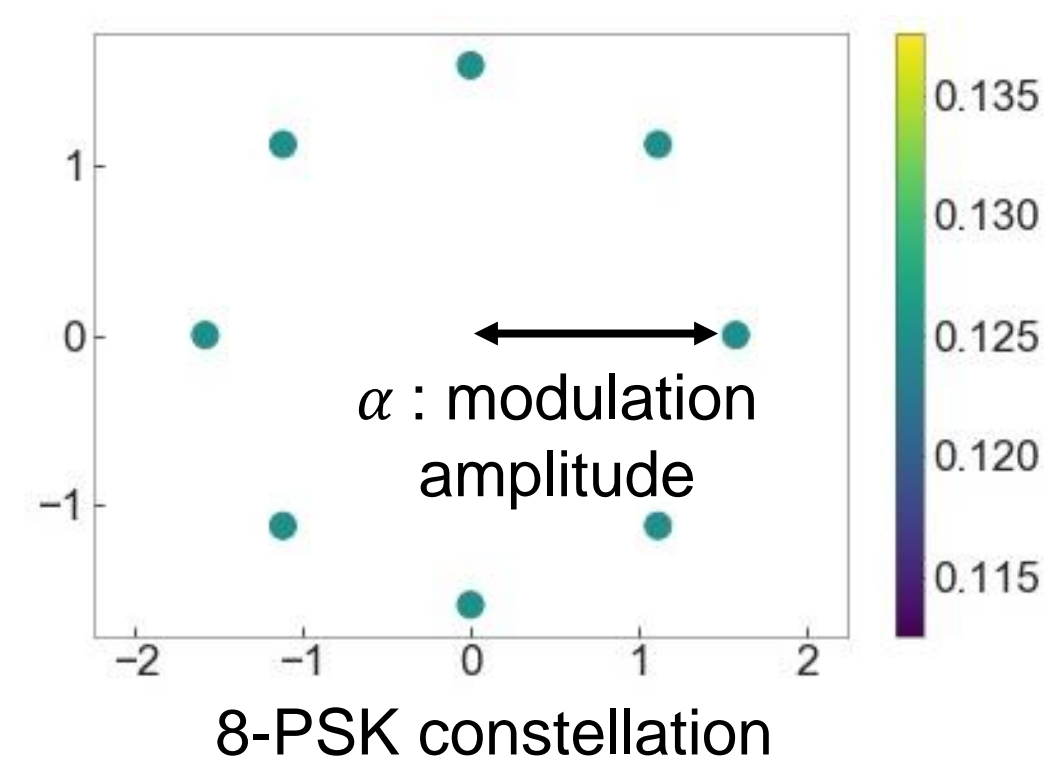
$$\sup_{N: A' \rightarrow B} \chi(Y; E) \leq f(\Gamma) \quad \text{where } \Gamma = \begin{bmatrix} V I_2 & Z \hat{\sigma}_z \\ Z \hat{\sigma}_z & W I_2 \end{bmatrix}$$

Z cannot be measured directly in the prepare & measure protocol \Rightarrow we write it as a Semidefinite Program (SDP)

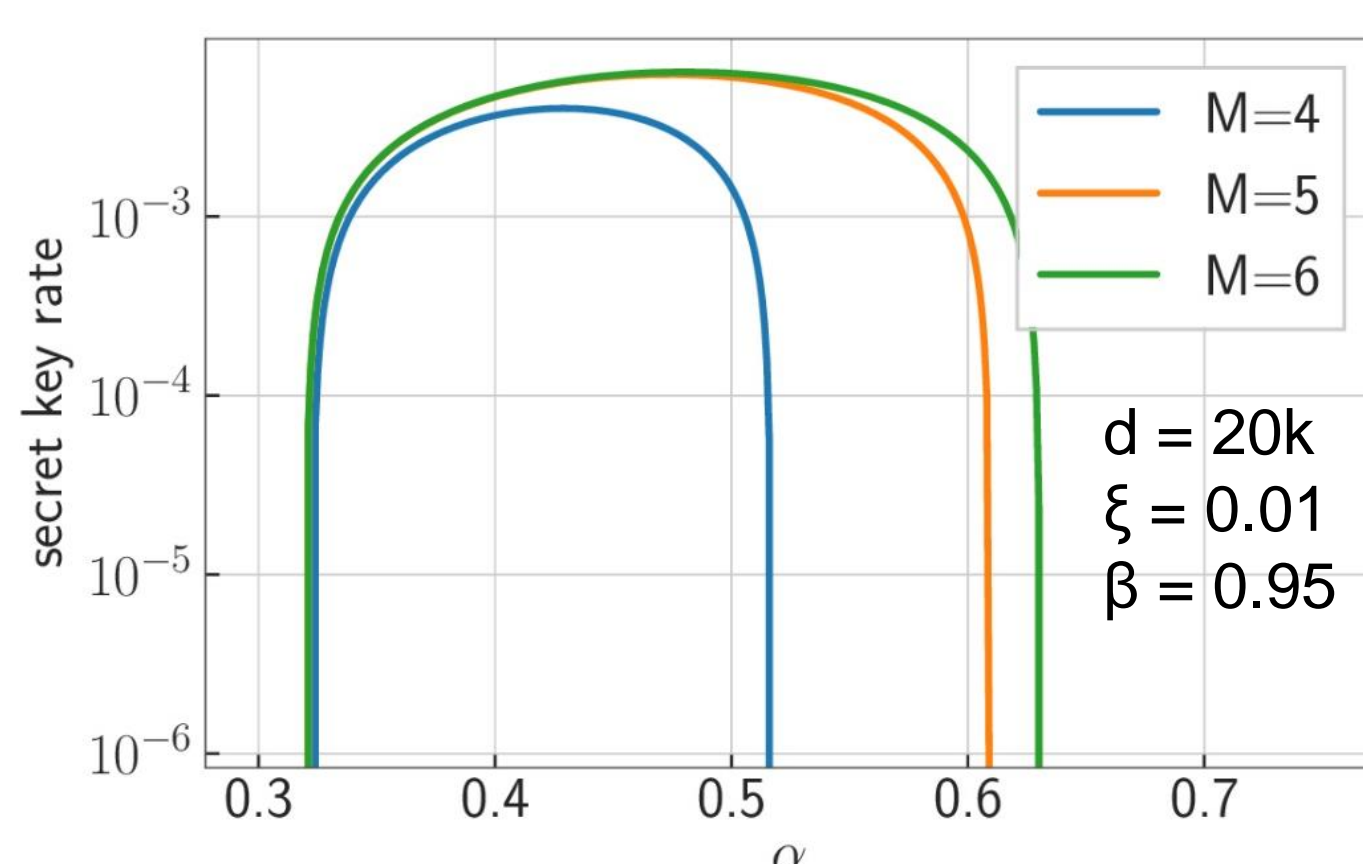
Bound on its solution: $Z \geq Z^* := 2 c_1 - 2 \left(\left(n_B - \frac{c_2^2}{n} \right) w \right)^{1/2}$ (*)

OPTIMAL CONSTELLATIONS?

Phase-shift keying modulations

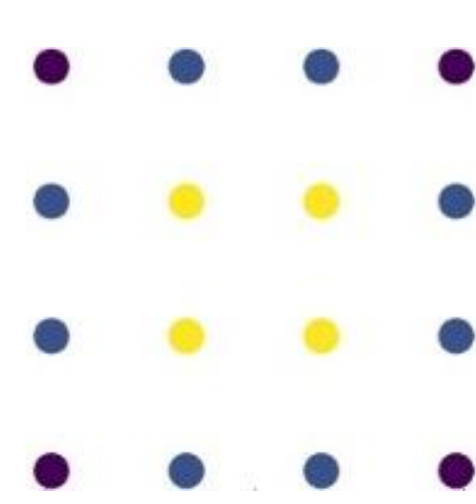


Asymptotic secret key rate as a function of the distance for the M-PSK modulation schemes.



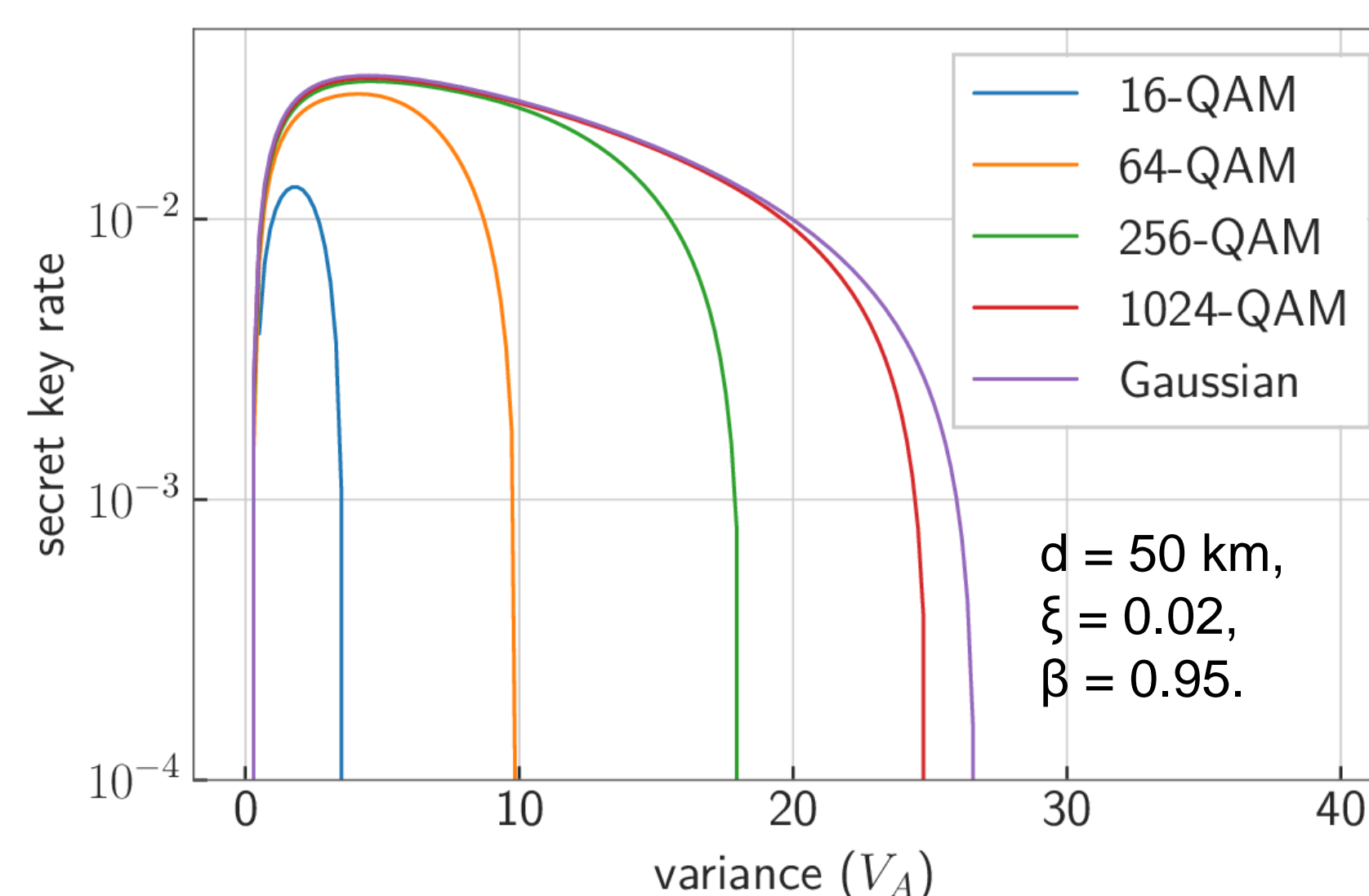
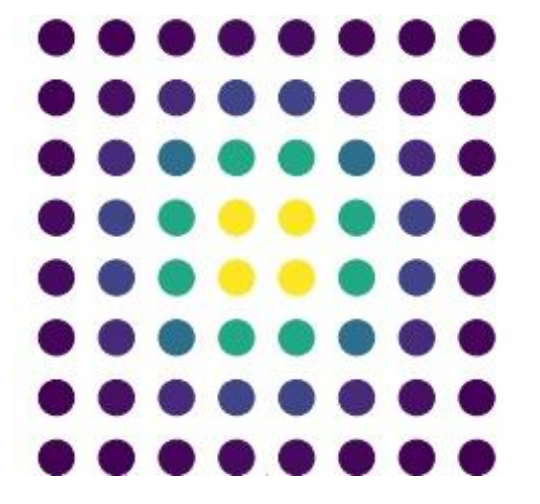
Asymptotic secret key rate as a function of the modulation amplitude for the M-PSK modulation schemes.

Quadrature amplitude modulations (QAM)

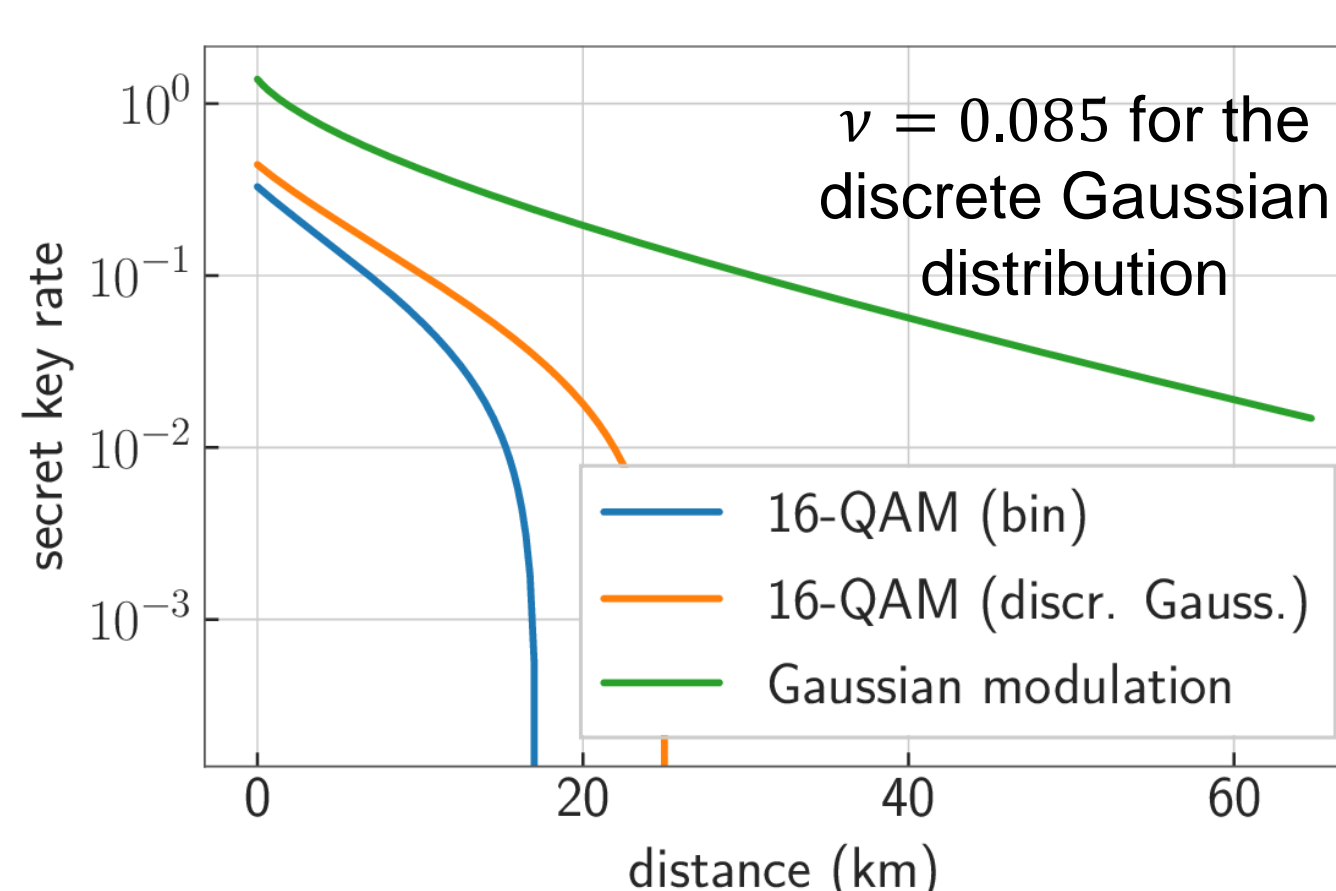


Before our work, only simple modulations (Gaussian modulation, quadrature phase-shift keying [1,2], etc.) could be analysed. The analytical formula (*) now makes possible the study of more relevant discrete modulations, such as the QAM.

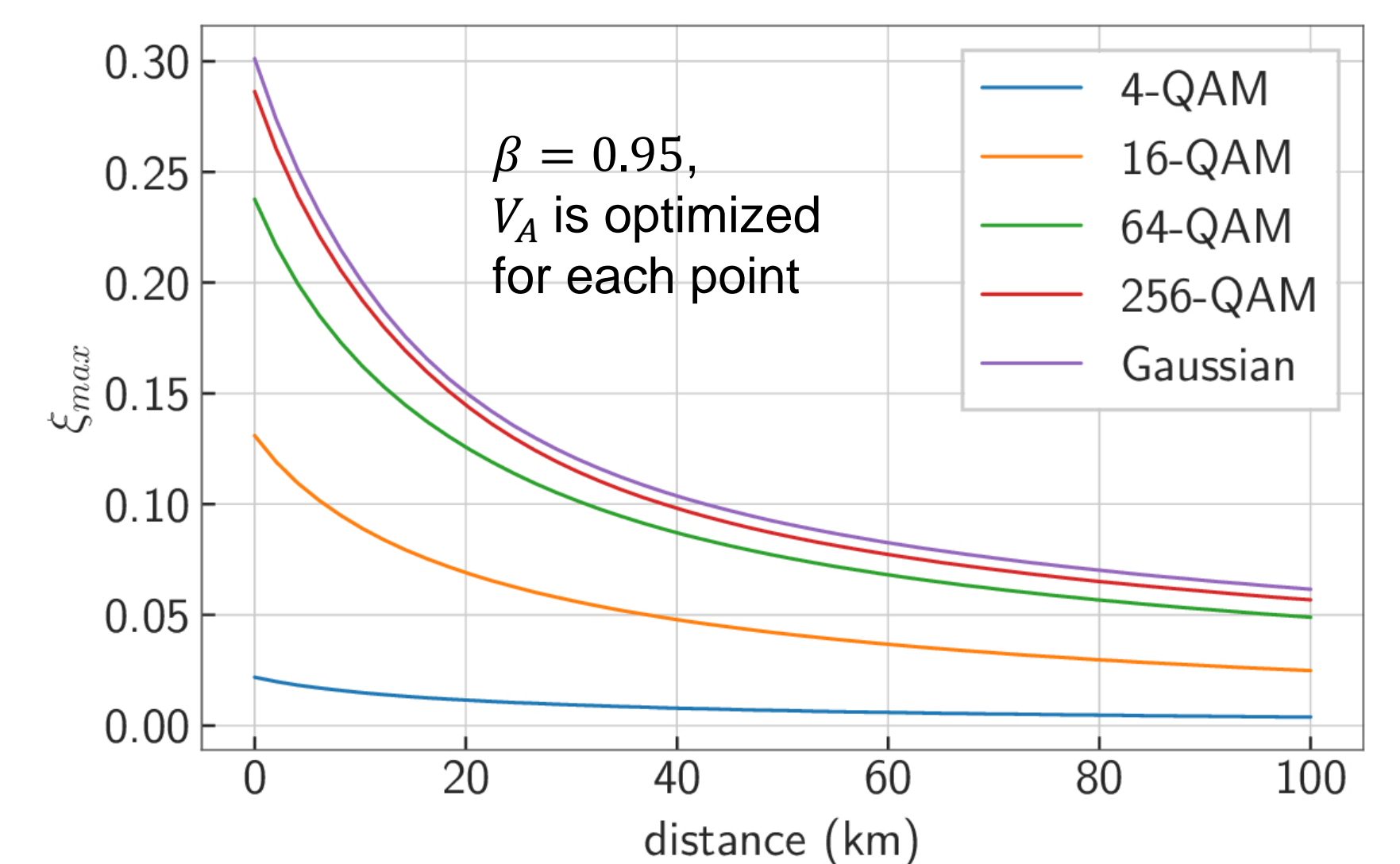
- [1] Ghorai et al., Phys. Rev. X, 9, 2, 021059, (2019)
[2] Lin et al., Phys. Rev. X, 9, 4, 041064, (2019)



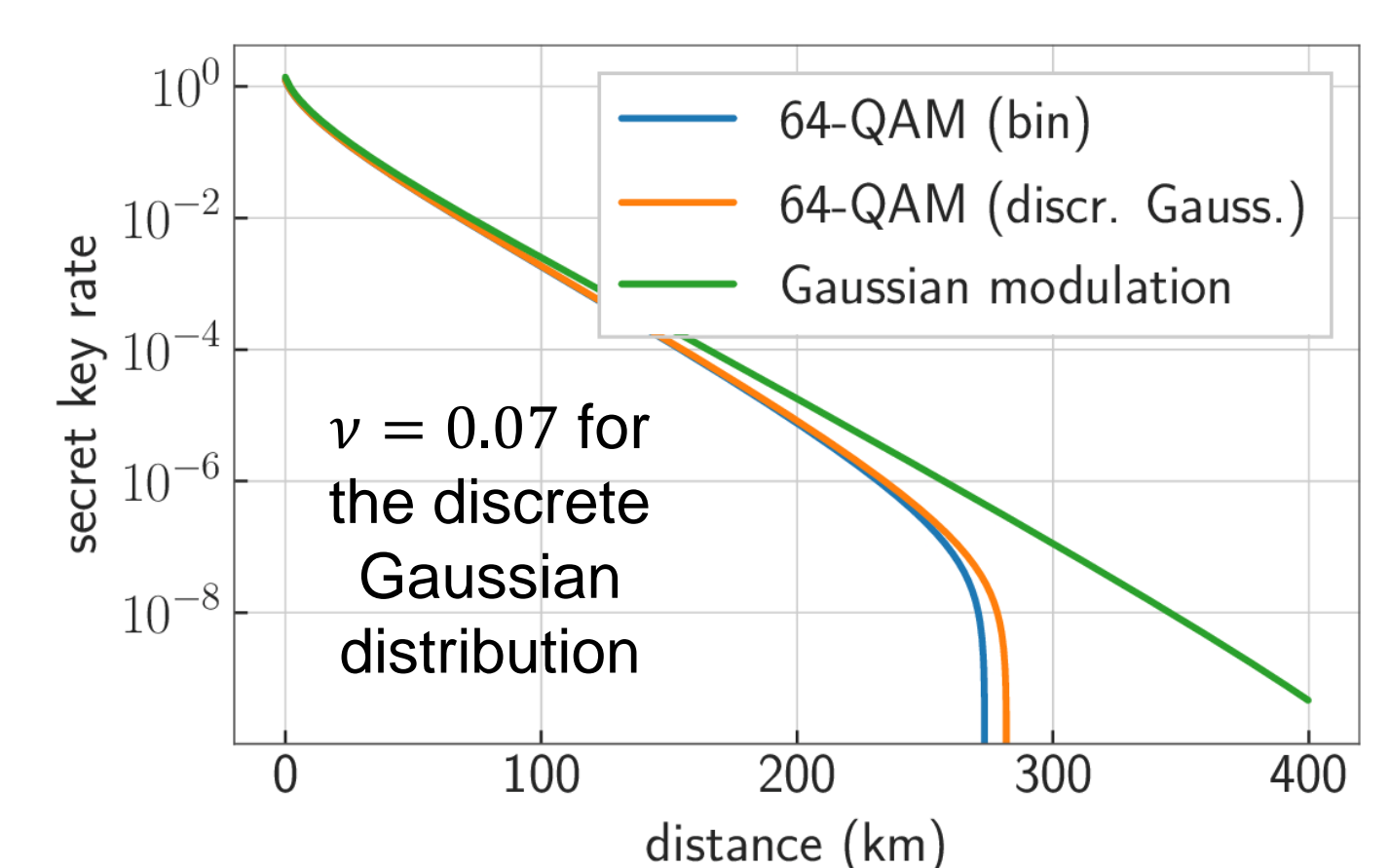
Secret key as a function of the modulation variance V_A , for various modulation schemes (with binomial distribution).



Bound on the asymptotic secret key rate as a function of the distance. Fixed parameters : $V_A = 5$, $\xi = 0.02$, $\beta = 0.95$



Maximum value ξ_{max} of excess noise compatible with a positive key rate as a function of the distance, for various QAM sizes (with binomial distribution).



Parameters: d : distance between Alice and Bob, V_A : modulation variance, ξ : excess noise, β : reconciliation efficiency, ν : parameter for the discretised Gaussian distribution.

“ Relatively small constellation sizes, with say 64 states, are essentially sufficient to obtain a performance close to a true Gaussian modulation ”