Collisional Thermometry for Gaussian Systems

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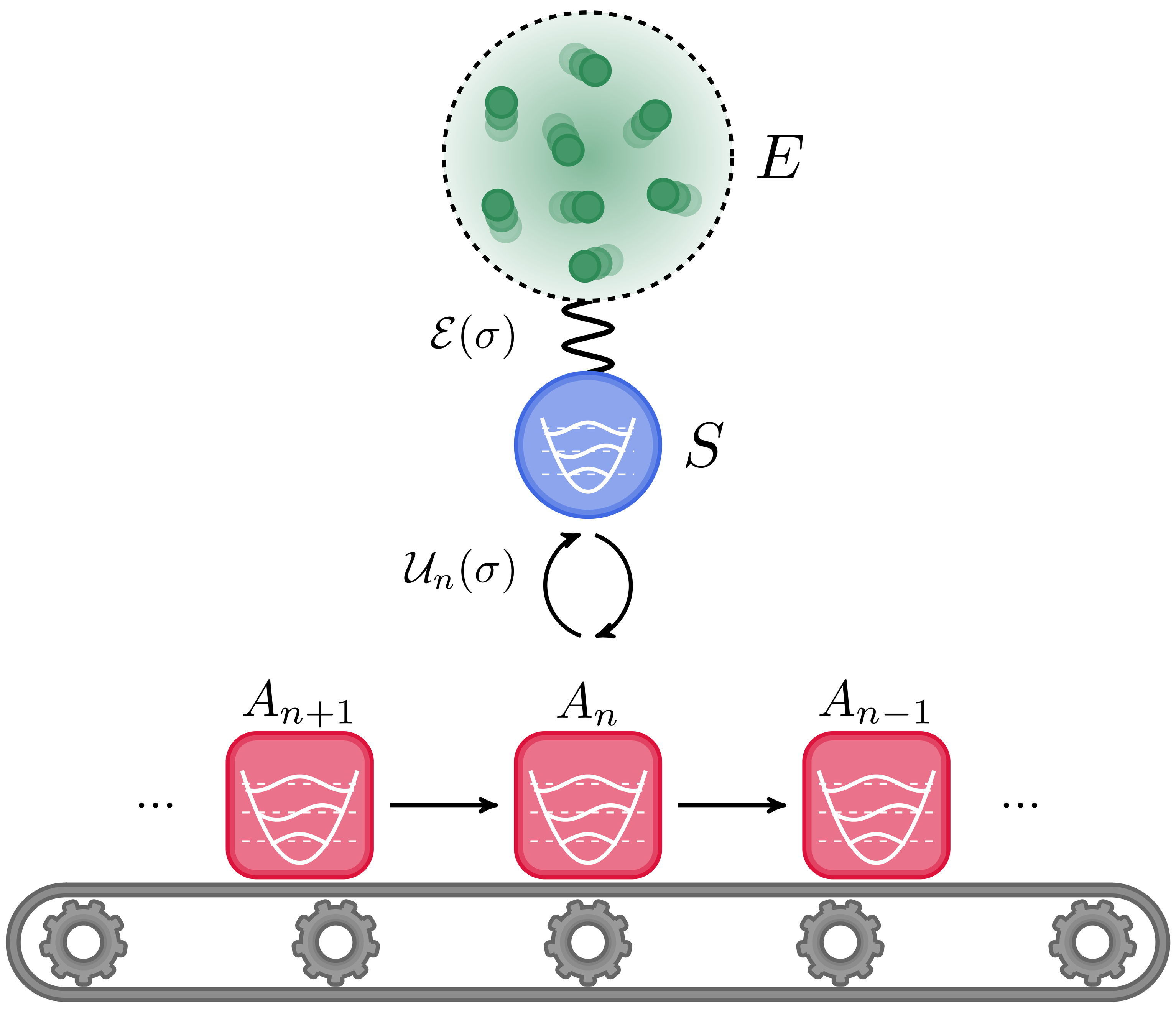
Introduction

Key open question: how does the Quantum Fisher Information (QFI) scale? Gaussian collision models allow for the scaling of the QFI to be evaluated for arbitrarily large sizes. We provide a simple phenomenological analysis for the behavior of the QFI, estimating the asymptotic Fisher information density and its scaling.

Collisional Model



- Beam splitter + two-mode squeezing Hamiltonian:

$$\sigma_{SA_i} \mapsto \mathcal{U}_i(\sigma_{SA_i}) = S_i \sigma_{SA_i} S_i^T \tag{1}$$

- Dissipative map through a Lindbladian:

$$\sigma_S \mapsto X \sigma_S X^T + Y, \tag{2}$$

- Compute the N-ancillae steady state $\Sigma^N = \mathrm{GTr}_S\left[\sigma^N\right]$.

Results

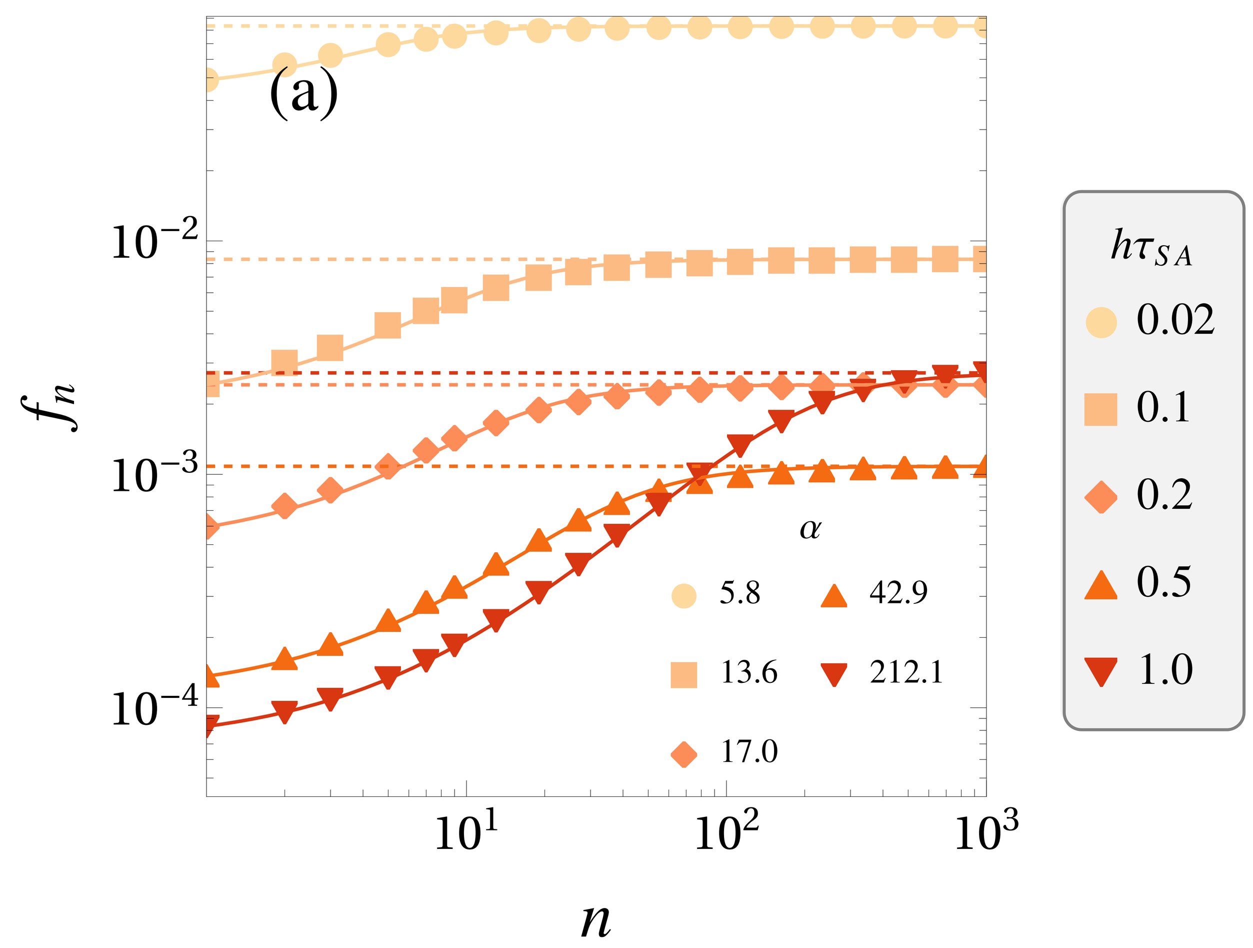
One can employ a simple expression to compute the QFI:

$$\mathcal{F}(\theta) = \frac{1}{2}\langle\partial\sigma_\theta|\,\mathcal{D}(\sigma_\theta)^{-1}\,|\partial\sigma_\theta\rangle\,, \tag{3}$$

defining the operator $\mathcal{D}(C) := (C \otimes C + \Omega \otimes \Omega)$ [2]. Our trick: perform a sympletic diagonalization *beforehand*!

Compute $\sigma = SWS^T$, given the symplectic eigenvalues computed from $i\Omega\sigma$. The QFI depends now on very sparse objects:

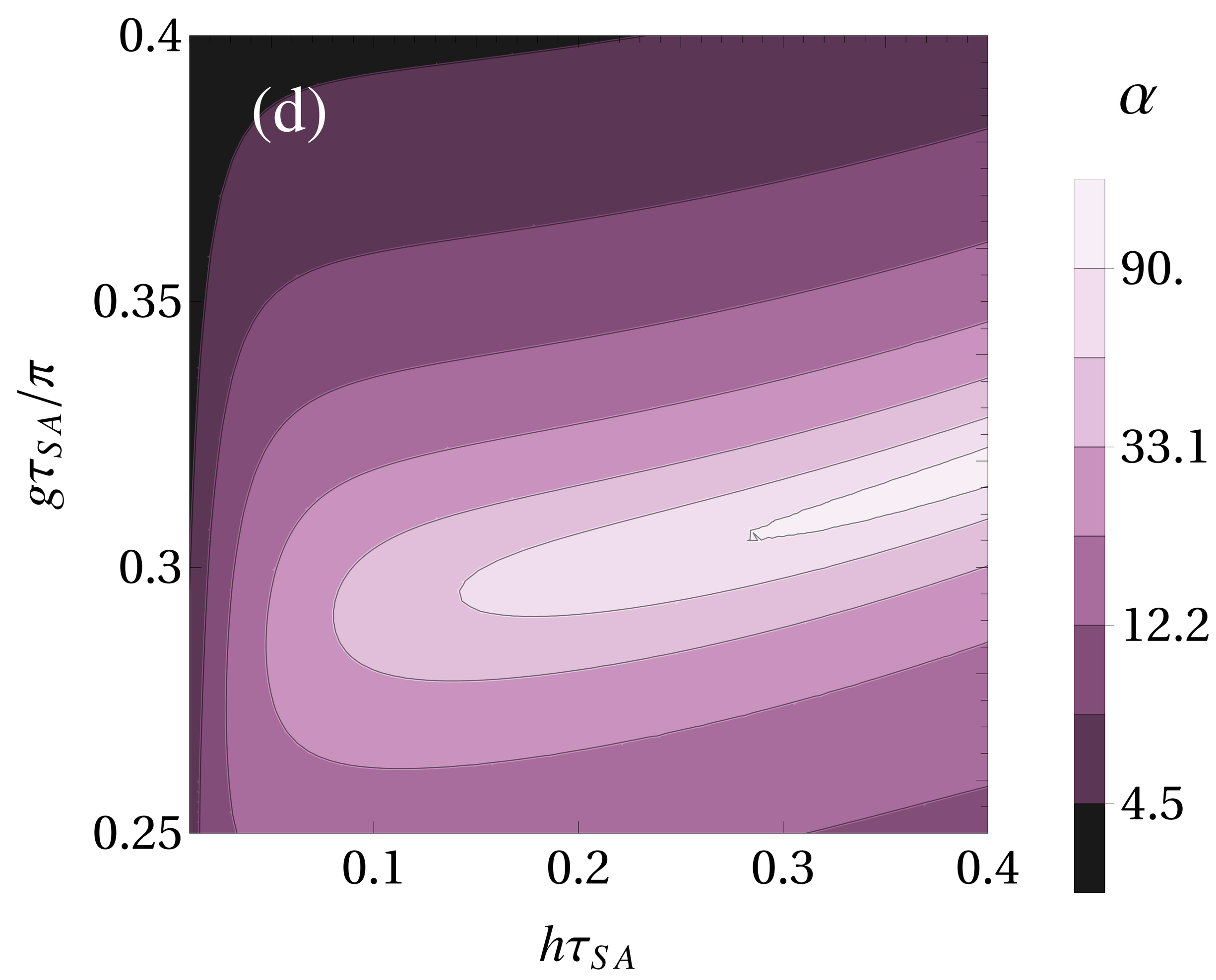
$$\mathcal{F}(\theta) = \frac{1}{2}\langle\partial\sigma_\theta|\,(S\otimes S)^{-T}\mathcal{D}(W)^{-1}(S\otimes S)^{-1}\,|\partial\sigma_\theta\rangle\,. \tag{4}$$



Through a numerical analysis we obtain a fit for the QFI density. The QFI density scales like a sigmoid:

$$f_{N+1} = f_1 + (f_\infty - f_1)\frac{N}{\sqrt{\alpha^2 + N^2}}. \tag{5}$$

One can define a QFI rate $f_\infty := \lim_{N\to\infty} f_N$, which can be achieved with precision ϵ for states with at least $N^* \sim \alpha\epsilon^{-1/2}$ ancillae (for $f_\infty \gg f_1$).



References & Acknowledgements

[1] Stella Seah, Stefan Nimmrichter, Daniel Grimmer, Jader P. Santos, Valerio Scarani, and Gabriel T. Landi, Physical Review Letters 123, 180602 (2019).

[2] Alex Monras, "Phase space formalism for quantum estimation of Gaussian states," (2013), arxiv:1303.3682.

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