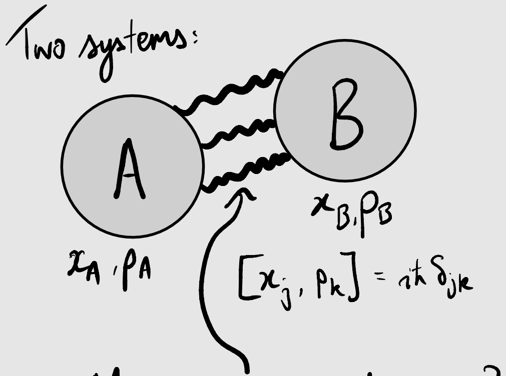
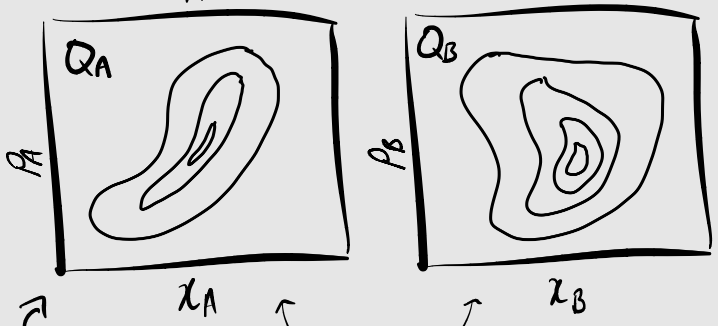
Entropic entanglement criteria in phase space

① Entanglement is hard to measure!

Two systems:



"Husimi" distributions



Measure entanglement?

⇒ measure x_A, p_A, x_B, p_B simultaneously

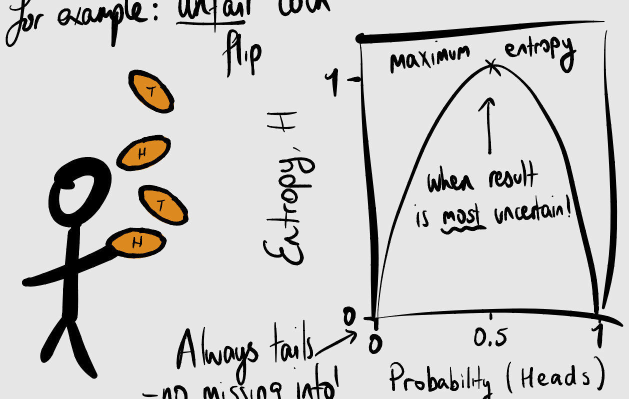
can be measured jointly in experiments:

e.g., quantum optics, ultracold atoms

② Entropy

In information theory, entropy measures "missing" information

for example: unfair coin flip



From our Husimi distributions, we can measure an entropy:

$$S = -\int \frac{dx_j\, dp_j}{2\pi} Q_j \ln Q_j$$

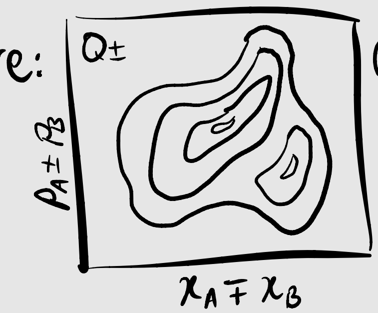
Why entropies?

Entropy can be used to witness entanglement!

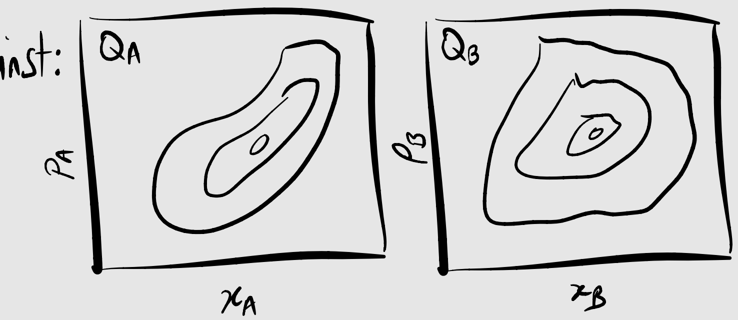
③ Our method

We use "twisted coordinates"

Compare:



against:



Our witness:

$$S(Q_\pm) \geq \ln\left(e^{S(Q_A)} + e^{S(Q_B)}\right) \geq 1 + \ln 2$$

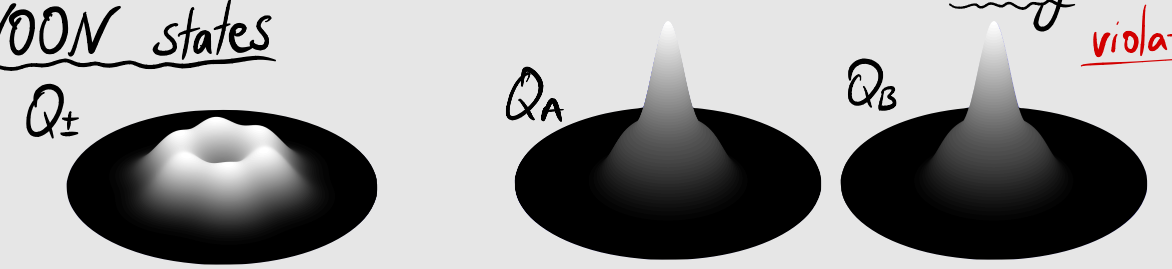
"Strong" criteria — "Weak" criteria

Violation = entanglement

④ Example states

NOON states

Strong criteria: violated



Schrödinger cat states

Weak criteria: violated

⑤ Future direction: incorporate memory; add more modes | Applications: Spinor Bose-Einstein condensates