HEP Interferometry via photon counting

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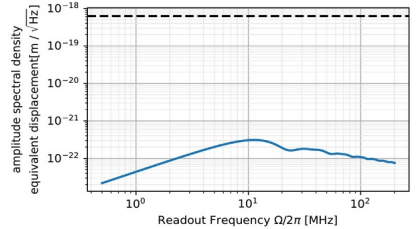
Interferometry & optomechanics:
- Profoundly sensitive to gravitational physics
- macroscopic quantum mechanics
- applications in DM detection

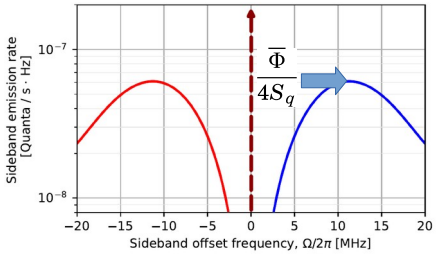
"wavelike" detectors limited by "quantum noise"
from homodyne readout or parametric amp readout

Make interferometry more like rare-process HEP
Signal power statistics → linear in time detection/exclusion
– no background "counts" from vacuum fluctuations
requires suitable search statistics

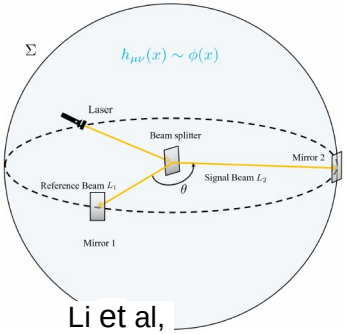


Small, wideband stochastic
metric fluctuation signal
Orders of magnitude below shot noise
~3 months for 1σ by incoherent search stat.

McCuller 2211.04016



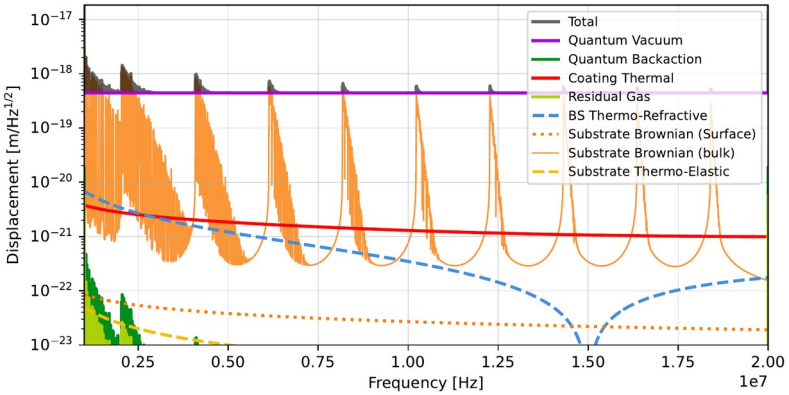
Equivalent sideband photopower
Emits 1 photon/second
Vastly accelerated search



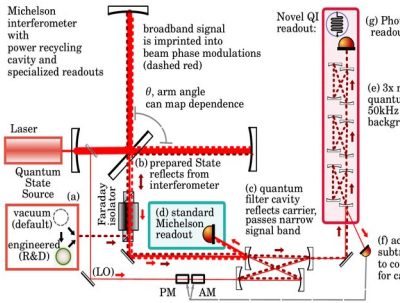
Li et al,
arXiv:2209.07543

GQuEST:

Gravity from Quantum Entanglement of Space-Time



Pathfinder for high-contrast
photon counting
10kW interferometer → mHz count rate



High-frequency signal amenable
to first attempts at counting
but requires new sophistication
→ unique design elements

Finds an entanglement-entropy
basis for gravitation - via
Metric fluctuation signature:

Banks, KZ 2108.04806
E. Verlinde, KZ 1902.08207
E. Verlinde, KZ 1911.02018

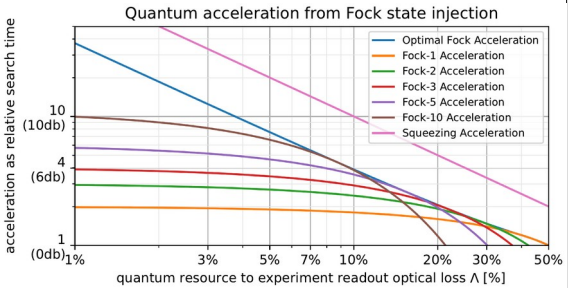
Novel Quantum Enhancements

LIGO's performance speaks volumes.
we've learned to saturate the benefits from squeezing.
Loss-engineering (in optical) will be
incremental and *trade* with higher power

Developing photon counting is a prerequisite to demonstrate *any* non-Gaussian observable at high contrast

Squeezing adds background counts → better quantum enhancements exist.

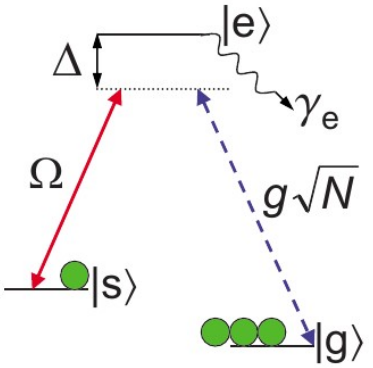
research quantum-enhanced Non-quadrature, non-Gaussian observables.



Generalized Counting

Employ quantum memories
implement matched-template search.
Generalize temporal-mode basis
beyond Lorentzian signal wavelets

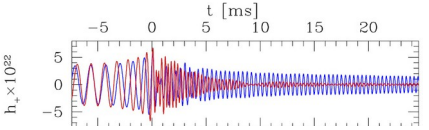
PhysRevA.76.033804



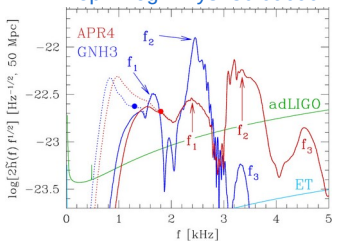
Science Goal

Binary Neutron Star inspiral "Equation of State"
strong-field nuclear matter in strong-field GR
Neutrino energy transport highly influences

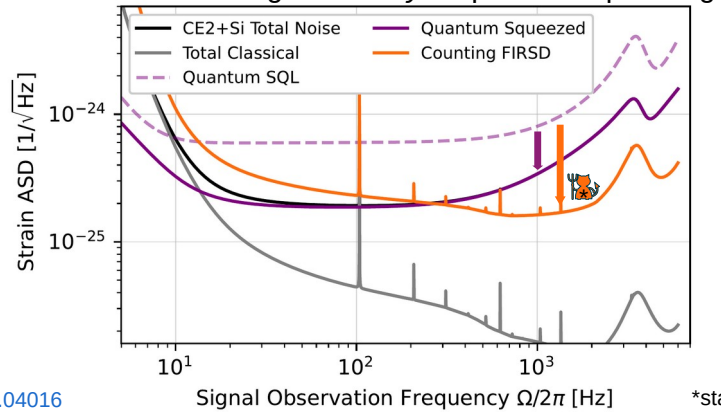
EOS information
conveyed in features
of neutron star waveforms



Rep. Prog. Phys. 80 09690



Proposed future detectors, e.g. Cosmic Explorer,
to detect 1e5 neutron stars/yr
Majority of total signal power near shot-noise limit
Photon counting can *vastly* outperform squeezing*



arXiv:2211.04016

CE2, 2um Cryo cSI Tech. W/ Photon counting

*statistic/informatic quantum tradeoffs inspire further study