# Gradient magnetometry with atomic ensembles

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We study gradient magnetometry with ensembles of atoms with arbitrary spin. We calculate precision bounds for estimating the gradient of the magnetic field based on the quantum Fisher information. For states that are sensitive to homogeneous fields, a simultaneous measurement is needed, as the homogeneous field must also be estimated. We present a method to calculate precision bounds for gradient estimation with two spatially separated atomic ensembles. We also consider a single atomic ensemble with an arbitrary density profile, where the atoms cannot be addressed individually, and which is a very relevant case for experiments.

## References

[1] I. Apellaniz, I. Urizar-Lanz, Z. Zimborás, P. Hyllus and G. Tóth, Phys. Rev. A, 97 (2018) 053603
[2] G. Vitagliano, M. Fadel, I. Apellaniz, M. Kleinmann, B. Lücke, C. Klempt, G. Tóth, arXiv:2104.05663 (2021)

## Figures

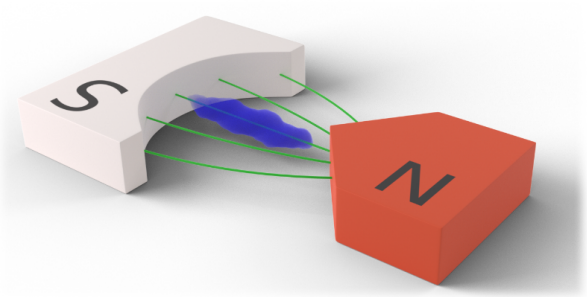


**Figure 1:** Schematic representation of an atomic ensemble (blue cloud) placed in a magnetic field (green lines) in a Stern-Gerlach apparatus. From the final state the gradient of the field can be estimated.

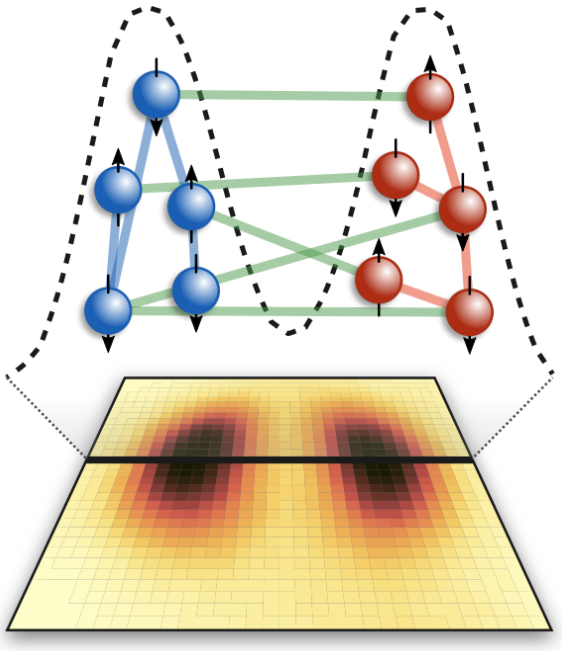

**Figure 2:** Atoms placed into two wells. Besides entanglement among particles belonging to the same well (red-blue lines), entanglement between the wells (green lines) can be used to overcome the shot-noise limit in gradient metrology.