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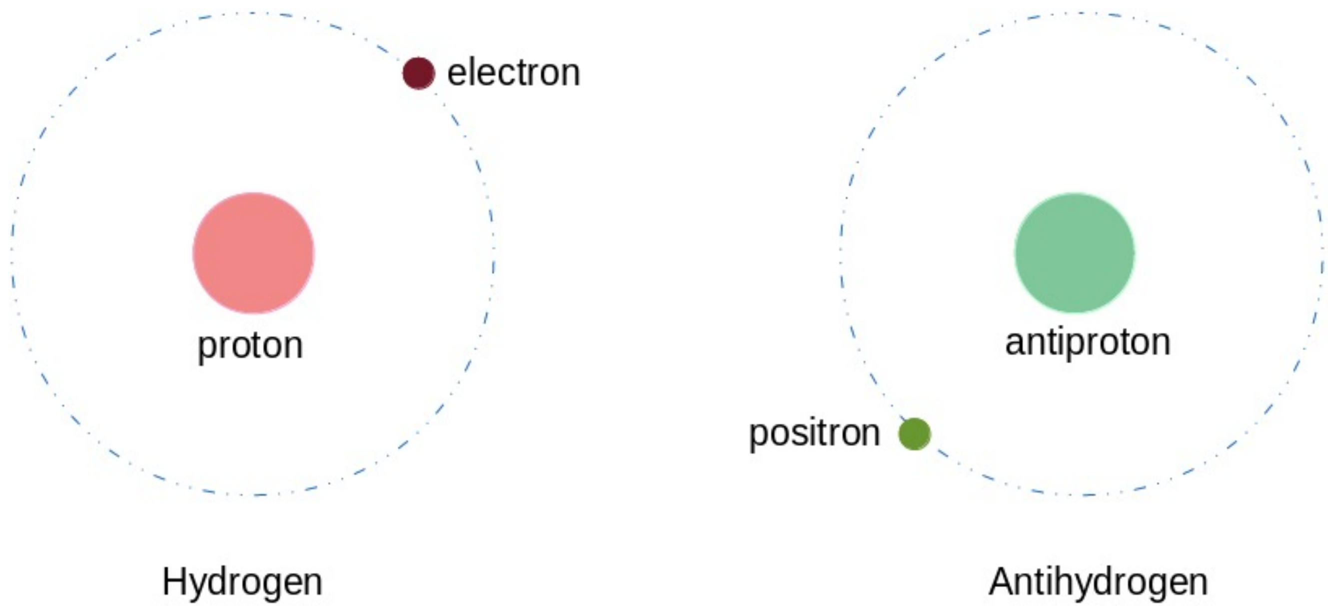
In situ magnetometry for experiments with antihydrogen

WNPPC 2022
18th February

Adam Powell
PhD student
University of Calgary
ALPHA collaboration

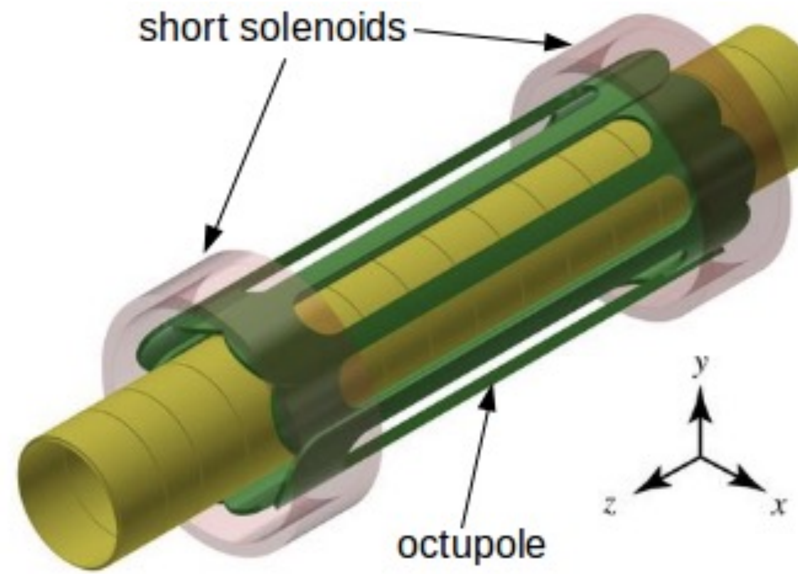
Why study antihydrogen?

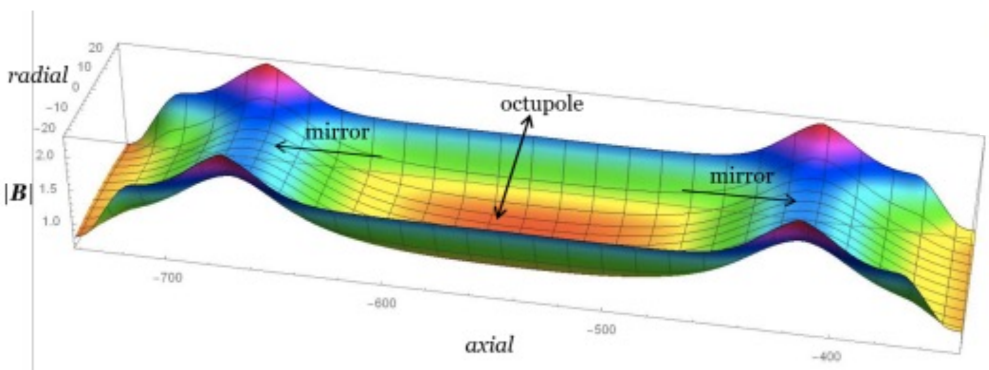


- Hydrogen has been studied extensively through history, comparing to antihydrogen can test CPT and QED

- Neutral so allows a test Weak-Equivalence-Principle in free fall experiments -> ALPHAg

Antihydrogen Laser Physics Apparatus (ALPHA)



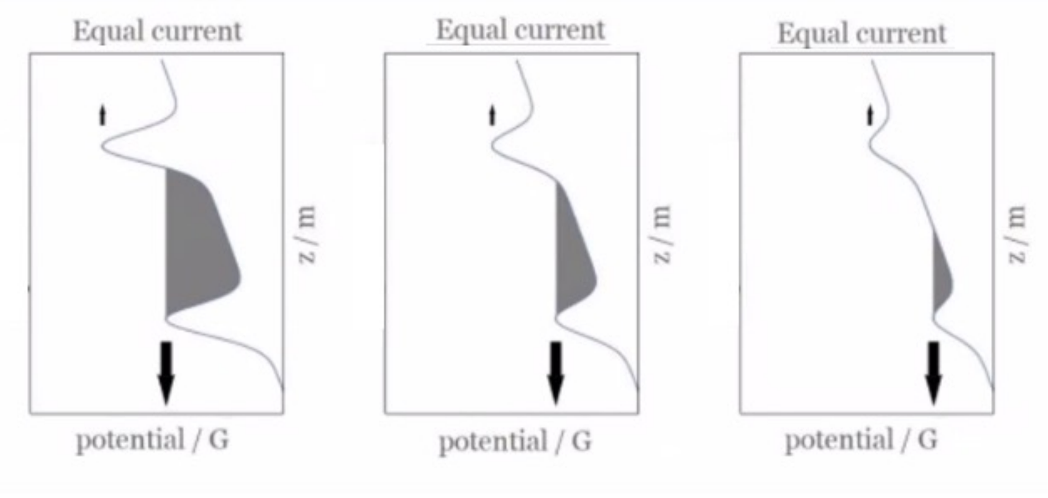


Quick recap on Wednesday's talks from Andrew, Pooja, and Gareth

Gravitational measurements in ALPHAg

- Gravitational potential difference of $\overline{H} < 10^{-4}\ T$ over 40 cm region of interest in our trap

- Need precise measurements of the magnetic fields around maximum regions to determine the difference in field required to balance gravity

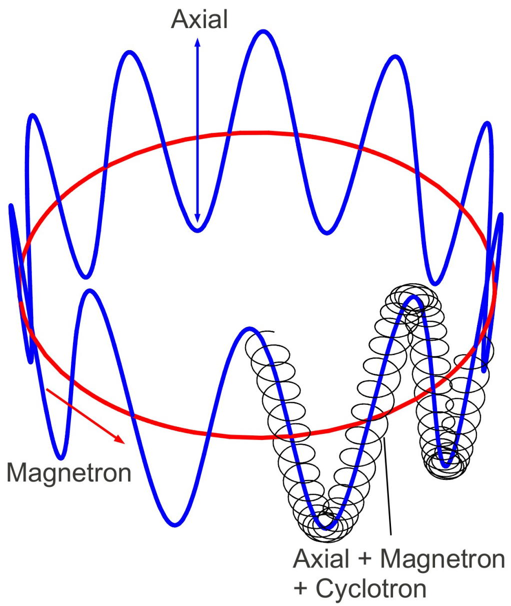


A. I. Zhmoginov, A. E. Charman, R. Shalloo, J. Fajans, and J. S. Wurtele, Class. and Quantum Grav. 30, 205014 (2013).

Using cyclotron frequency for magnetometry

$$f_c = \frac{q\,B}{2\,\pi\,m}$$

f_c at $1\,T \sim 28$ GHz



But…the cyclotron motions isn’t all that happens in a Penning trap

Axial frequency ~ 10 - 50 MHz

Magnetron frequency ~ 100 - 300 kHz

Electron cyclotron resonance magnetometry technique

- Irradiate electron plasma with microwaves and measure temperature (destructively)

- Repeat many times with a new electron plasmas at different microwave frequencies

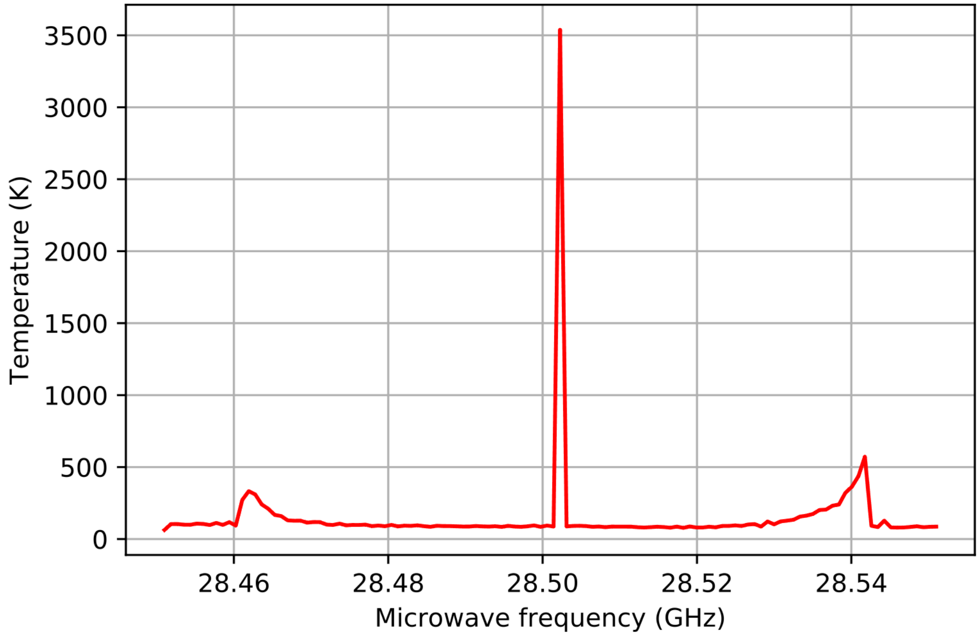
- Temperature increases -> microwave frequency = f_c

  (…also at $f_c \pm$ other trap motions)

Electron Cyclotron Resonance (ECR) Magnetometry with a Plasma Reservoir
E. D. Hunter, A. Christensen, J. Fajans , T. Friesen, E. Kur, and J. S. Wurtele (2019)

An example of ECR in a 1T field

- Narrow central peak = f_c
- Precision related to peak width
- Broad, asymmetric sidebands from electrons axial frequency



Magnetic field measurements around a maximum

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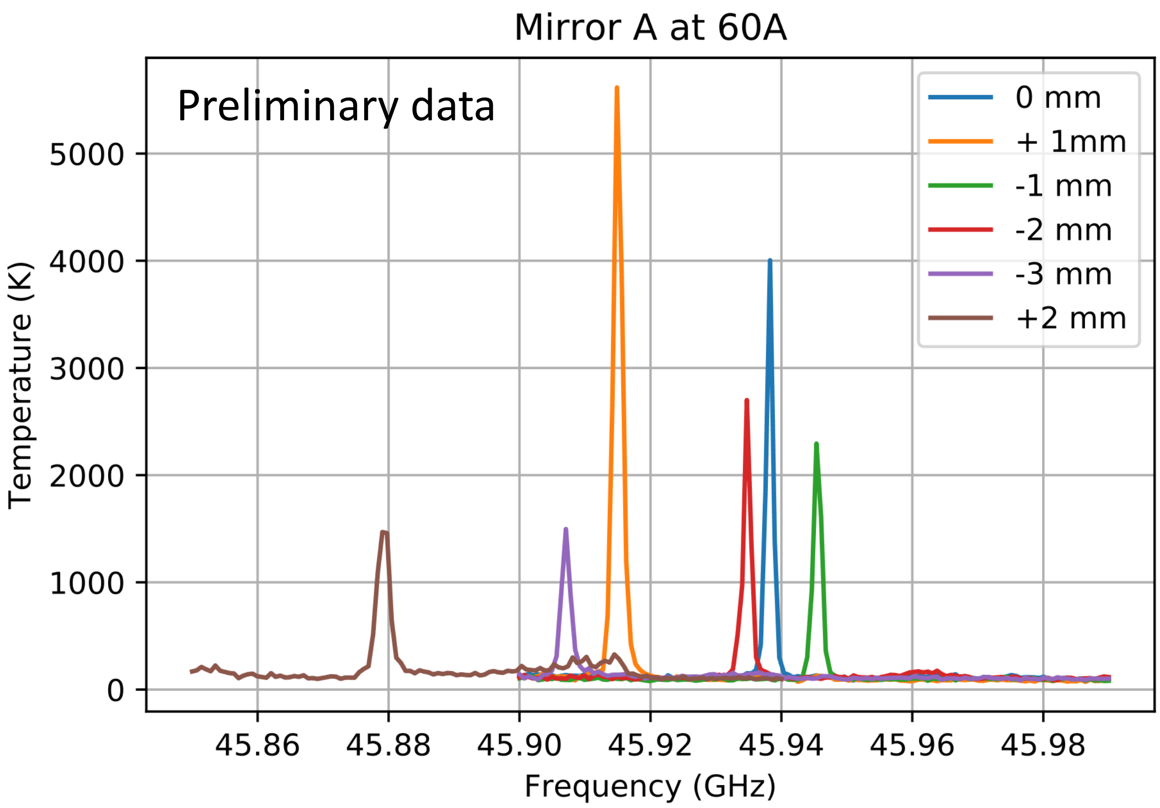
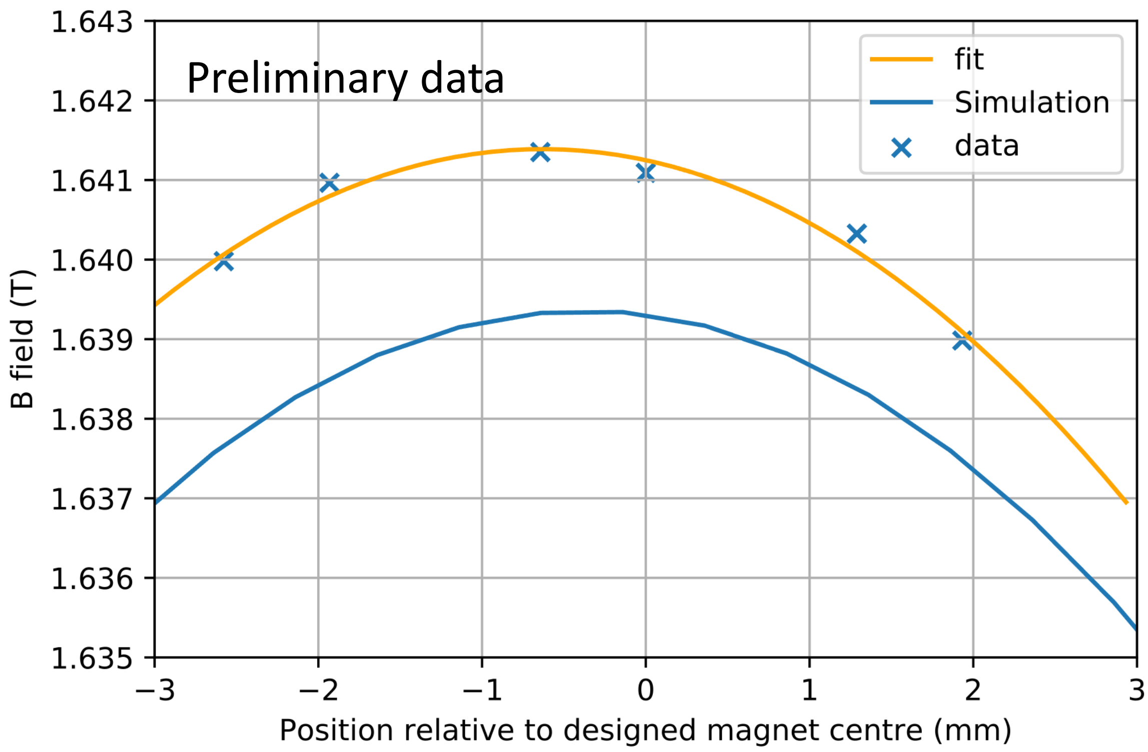


Note: legend is approximate values of a shift away from expected centre of the magnet

Magnetic field measurements around a maximum



Summary

- Gravitational measurements of antihydrogen in ALPHAg require precise magnetic field measurements
- In situ magnetometry technique has been developed in ALPHA to reach this precision
- We have made progress mapping our new magnets to prepare for gravity measurements in 2022
- But a lot more to come!

Thank you to:

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