Towards an order of magnitude improvement in high-precision atomic mass measurements

Simon Rainville
James K. Thompson
Prof. David E. Pritchard

Michael P. Bradley
Trey Porto

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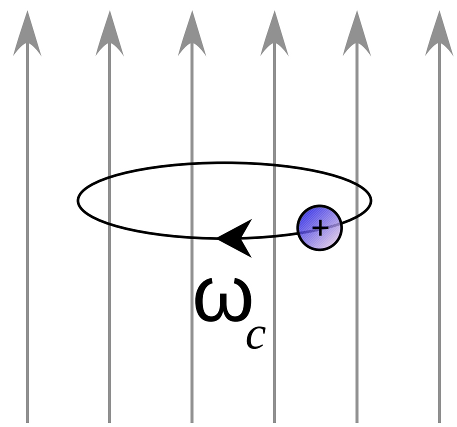
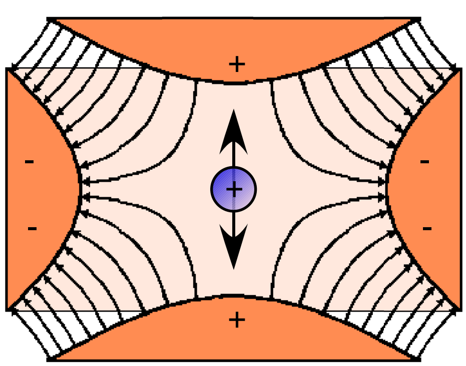
Massachusetts Institute of Technology, Cambridge MA

Single Ion Mass Spectrometry



Cyclotron motion $\omega_c = \dfrac{qB}{m}$

$$\frac{\omega_{c1}}{\omega_{c2}} = \frac{q_1}{q_2}\frac{m_2}{m_1}$$



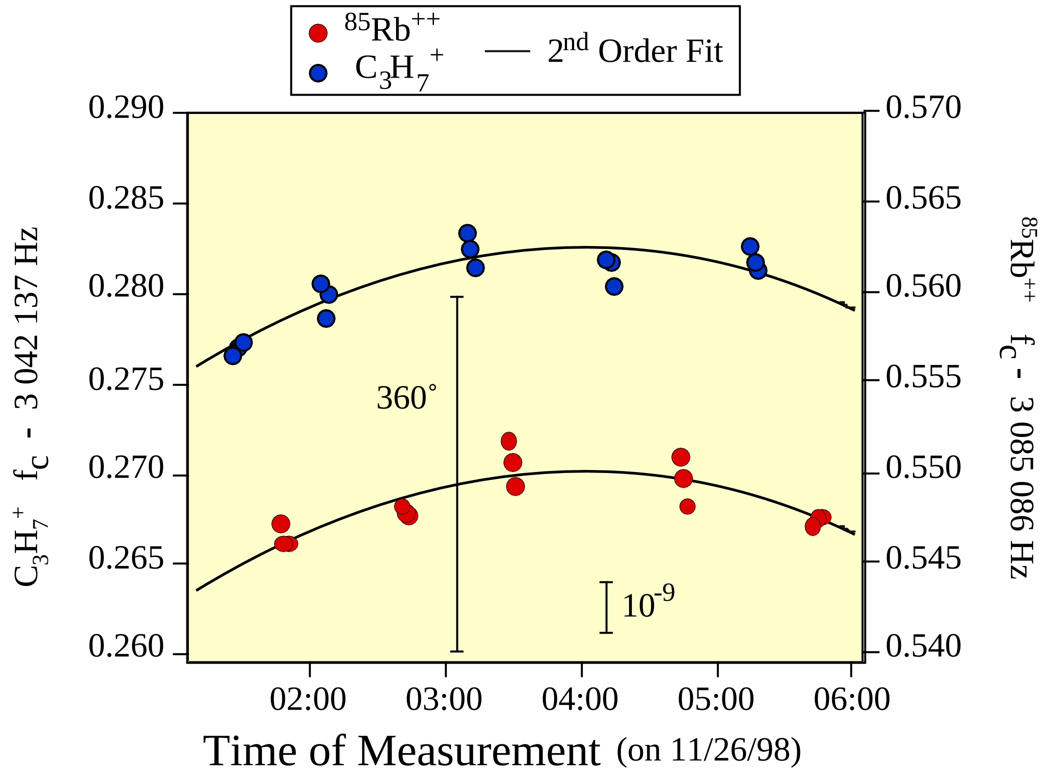
Harmonic Axial motion $\dfrac{\omega_z}{2\pi} \approx 200\text{ kHz}$

Use mode coupling techniques to measure

$$\omega_c/2\pi \approx 5\text{ MHz}$$

Slow Magnetron motion (usually ignore) $\dfrac{\omega_m}{2\pi} \approx 5\text{ kHz}$

Single Ion data



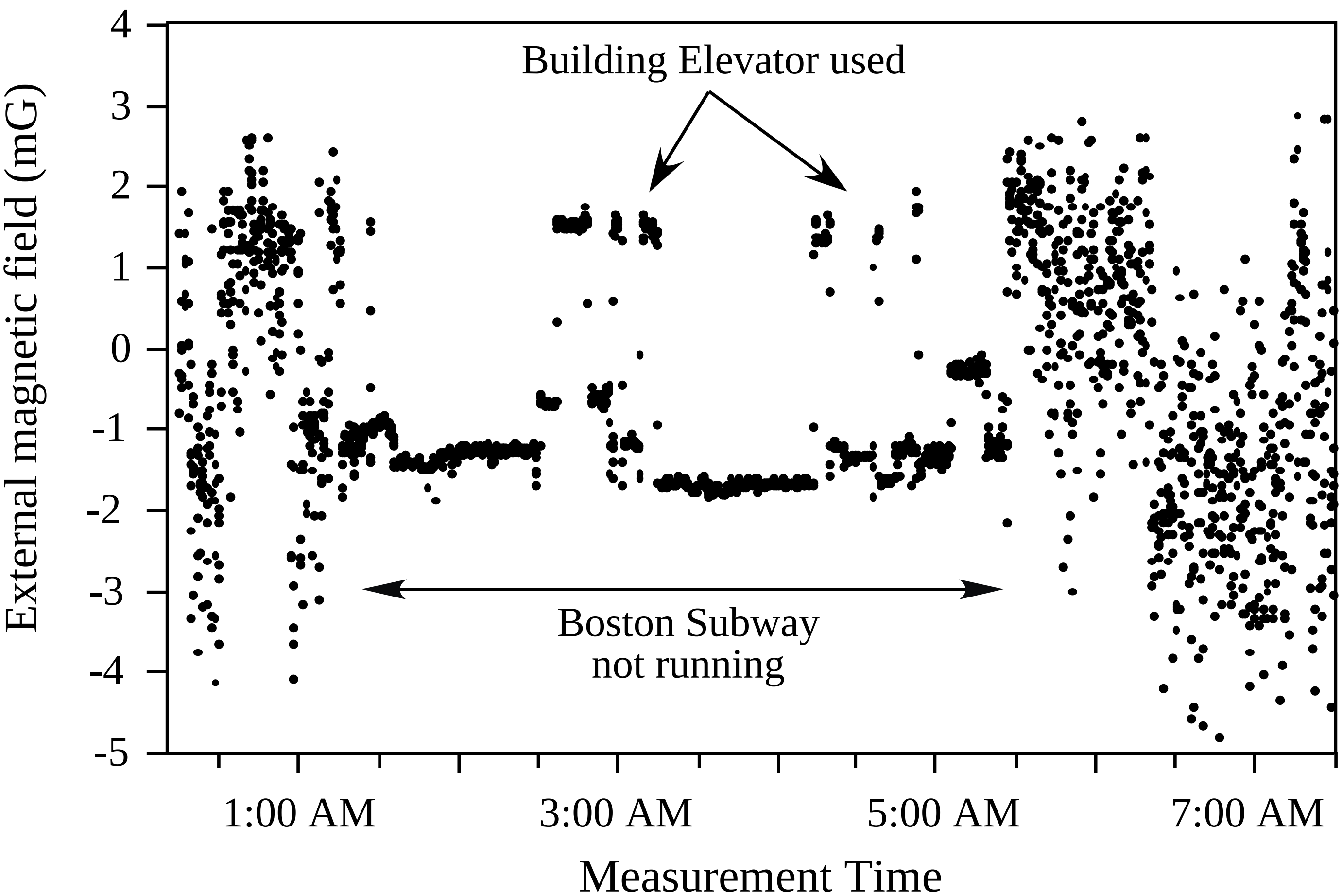
- 5 - 30 minutes to isolate a new single ion
- Precision of 10^{-10} for a full run (4 hours)

MIT Mass Table

Element	Δm/m (x 10^{-10})	Factor of improvement	Element	Δm/m (x 10^{-10})	Factor of improvement
H	5.0	24	^{23}Na	1.2	93
^{2}H	2.5	48	^{28}Si	0.7	350
^{13}C	0.8	17	^{40}Ar	0.8	424
^{14}N	0.9	22	^{85}Rb	1.6	193
^{15}N	0.7	36	^{87}Rb	1.7	187
^{16}O	1.3	24	^{133}Cs	2.0	111
^{20}Ne	1.2	957			

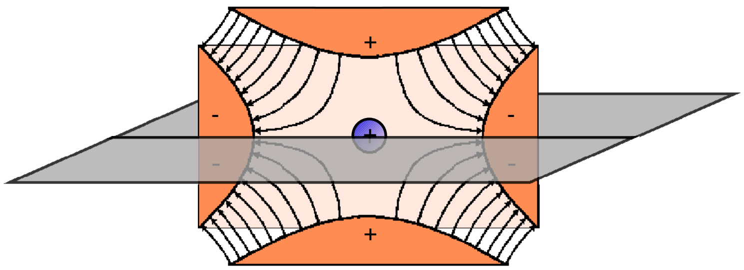
Main Limitation of Single Ion Technique:

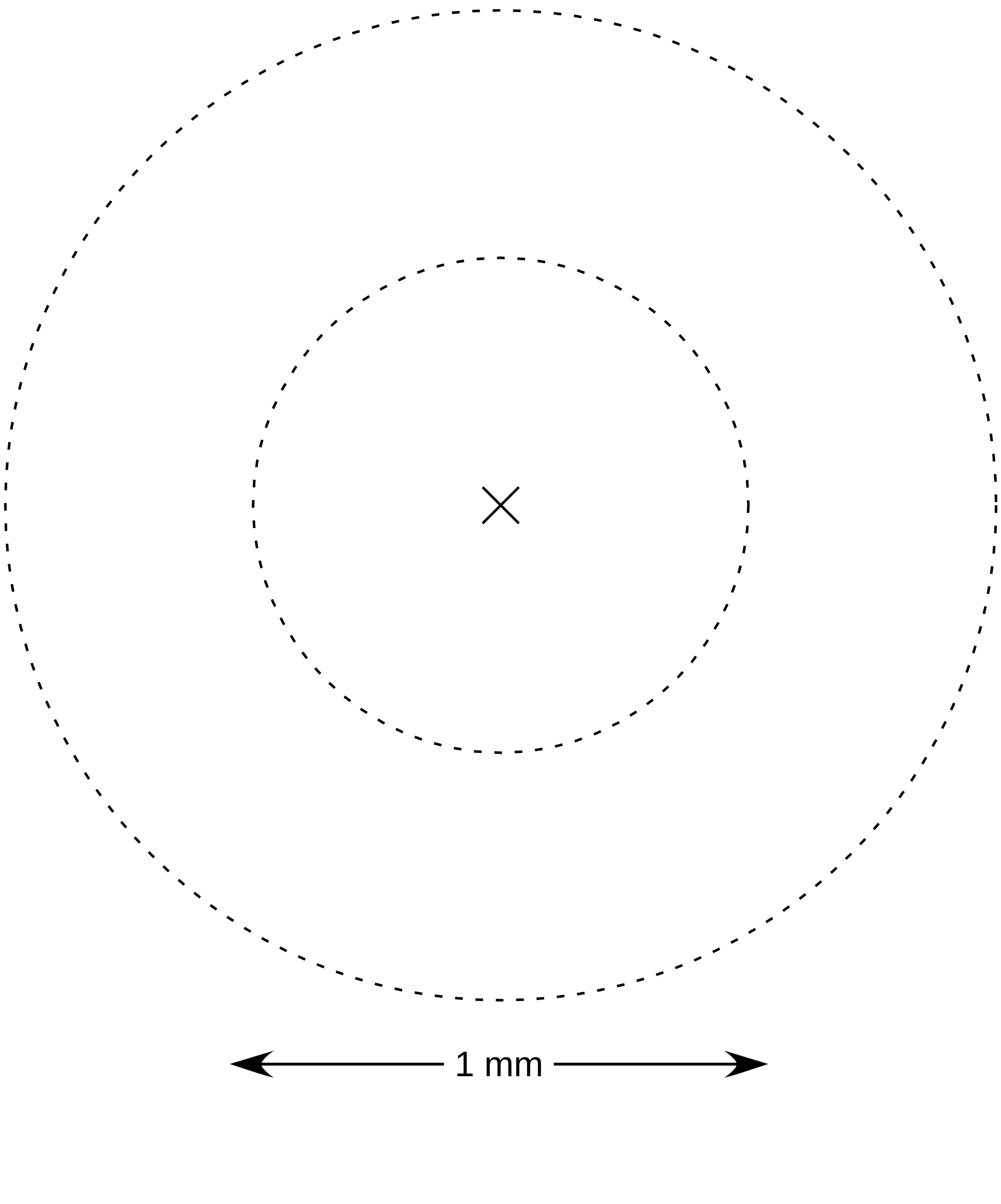
Magnetic Field Noise



Want to make SIMULTANEOUS measurements

Two Ions in One Trap



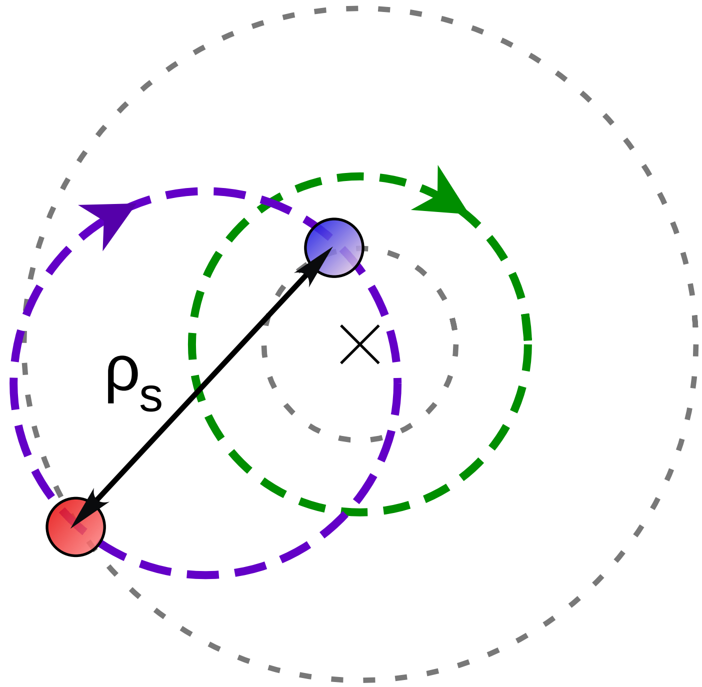


Two Ions in One Trap

$m_1 \approx m_2$

⇩

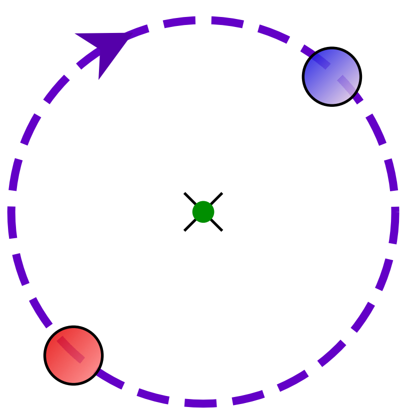
New normal modes:
- center-of-mass
- difference



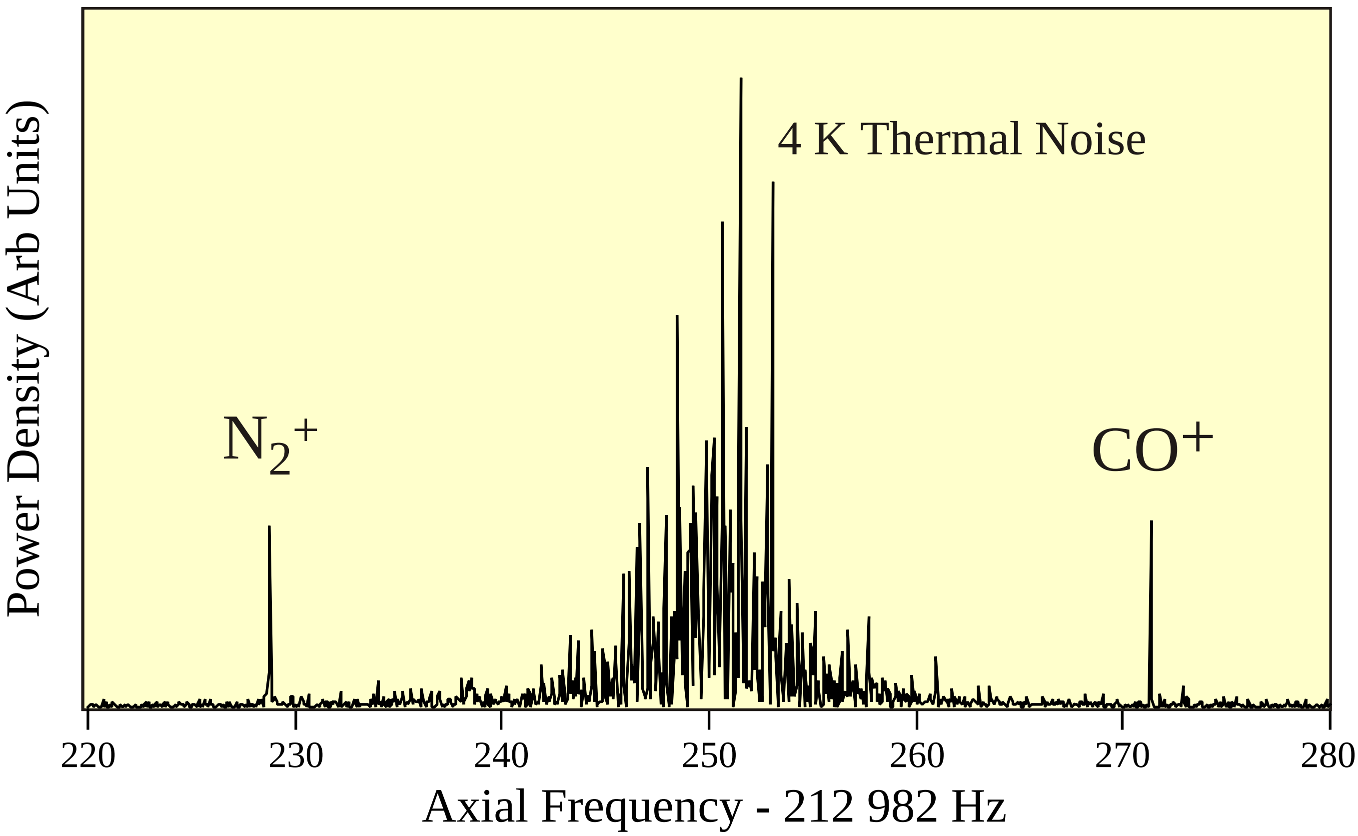
- ρ_s is constant
- $\rho_s \approx 0.5$ - 1 mm

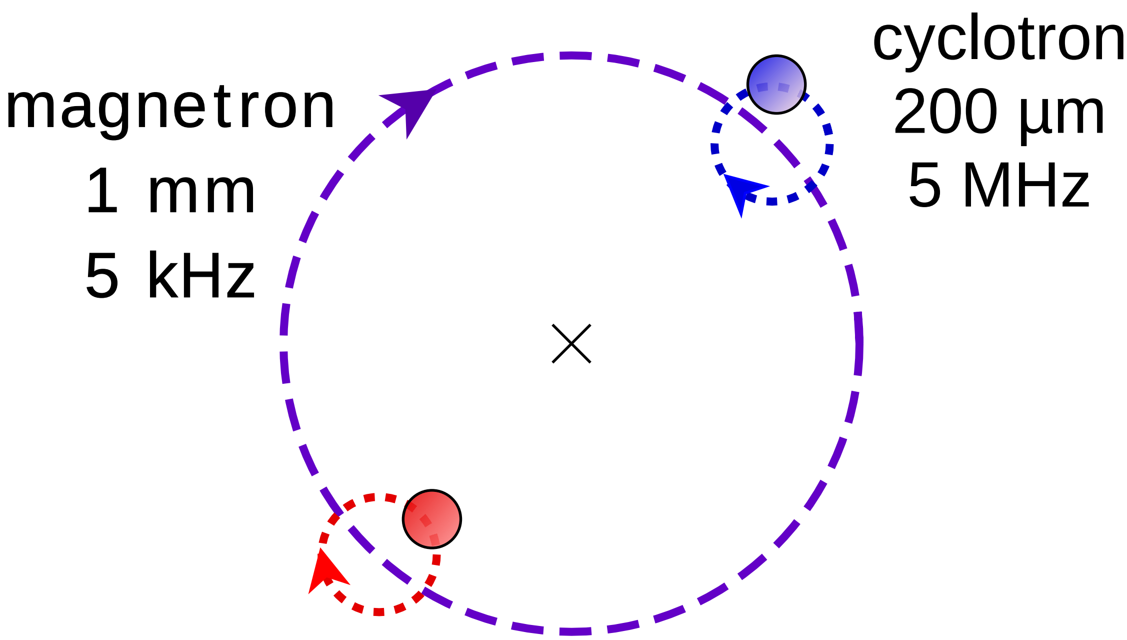
perturbation $< 2 \times 10^{-12}$ on mass ratio

Want $\rho_{com} \approx 0$ for the two ions to sample the same average magnetic field.

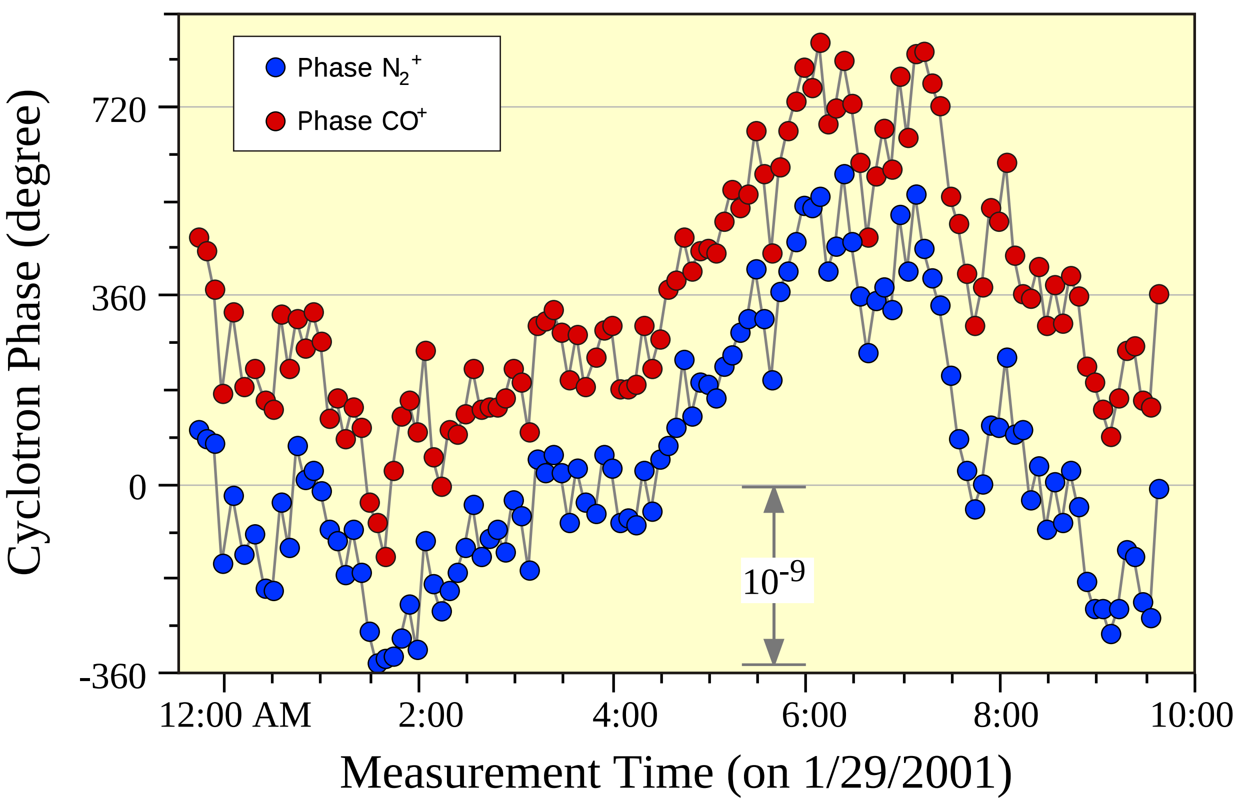


Simultaneous Measurements on Two Ions

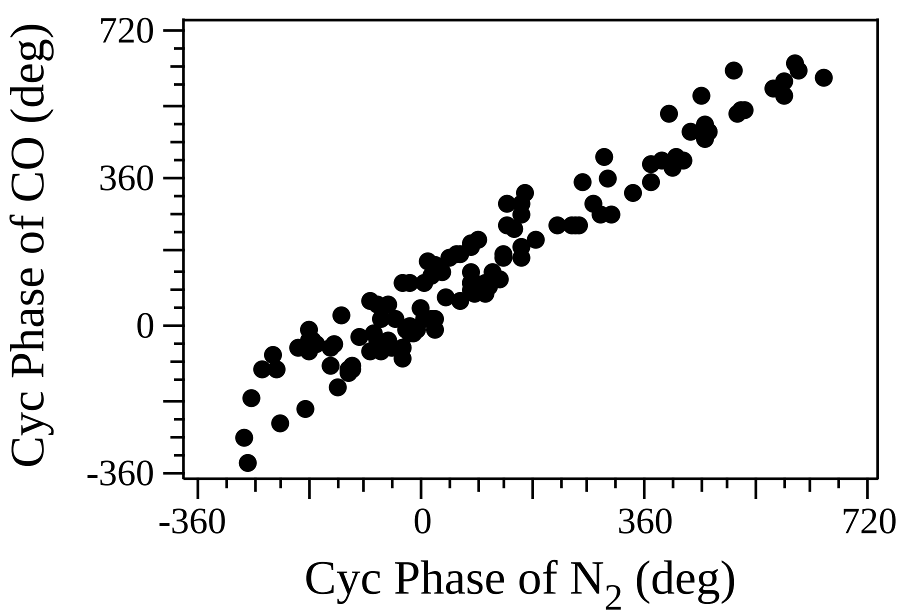




Preliminary Two Ions Data

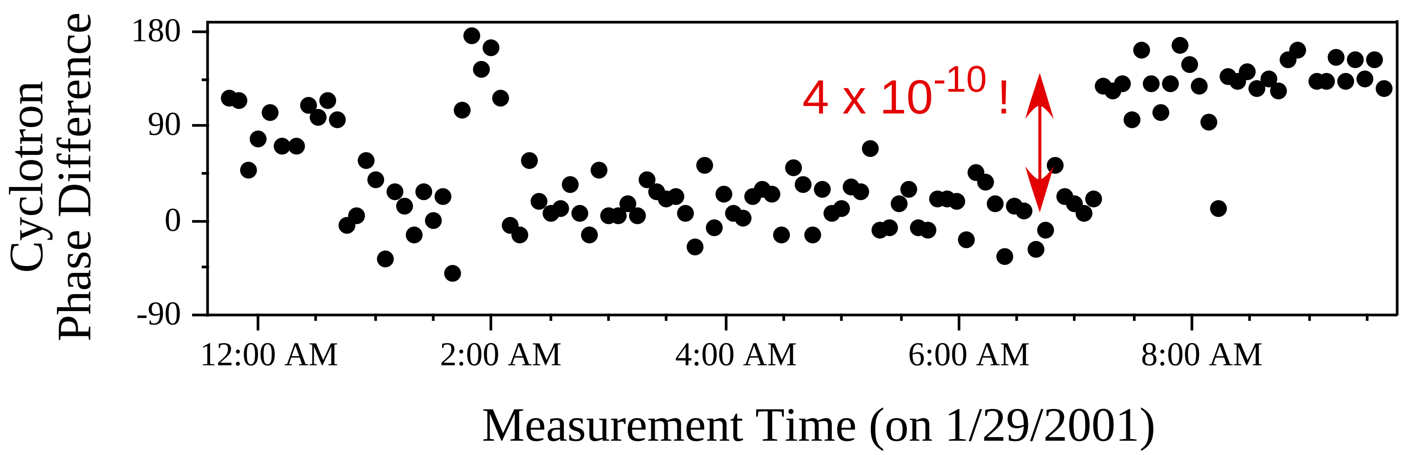


Precision of 10^{-10} in
4 minutes (during the day) !!



Current and Future Work

Big jumps in cyclotron frequency difference:
- ions decouple ?
- change in separation distance ?



Tools to observe and control trajectories of 2 ions:
- Anharmonicities $\omega_z(\rho)$
- Transfer a little bit of ρ_{mag} into axial motion, to measure the ion's radial position.
  - diagnostic
  - fine-tune orbits
  - study possible systematic errors

Simultaneous Measurements on Two Ions