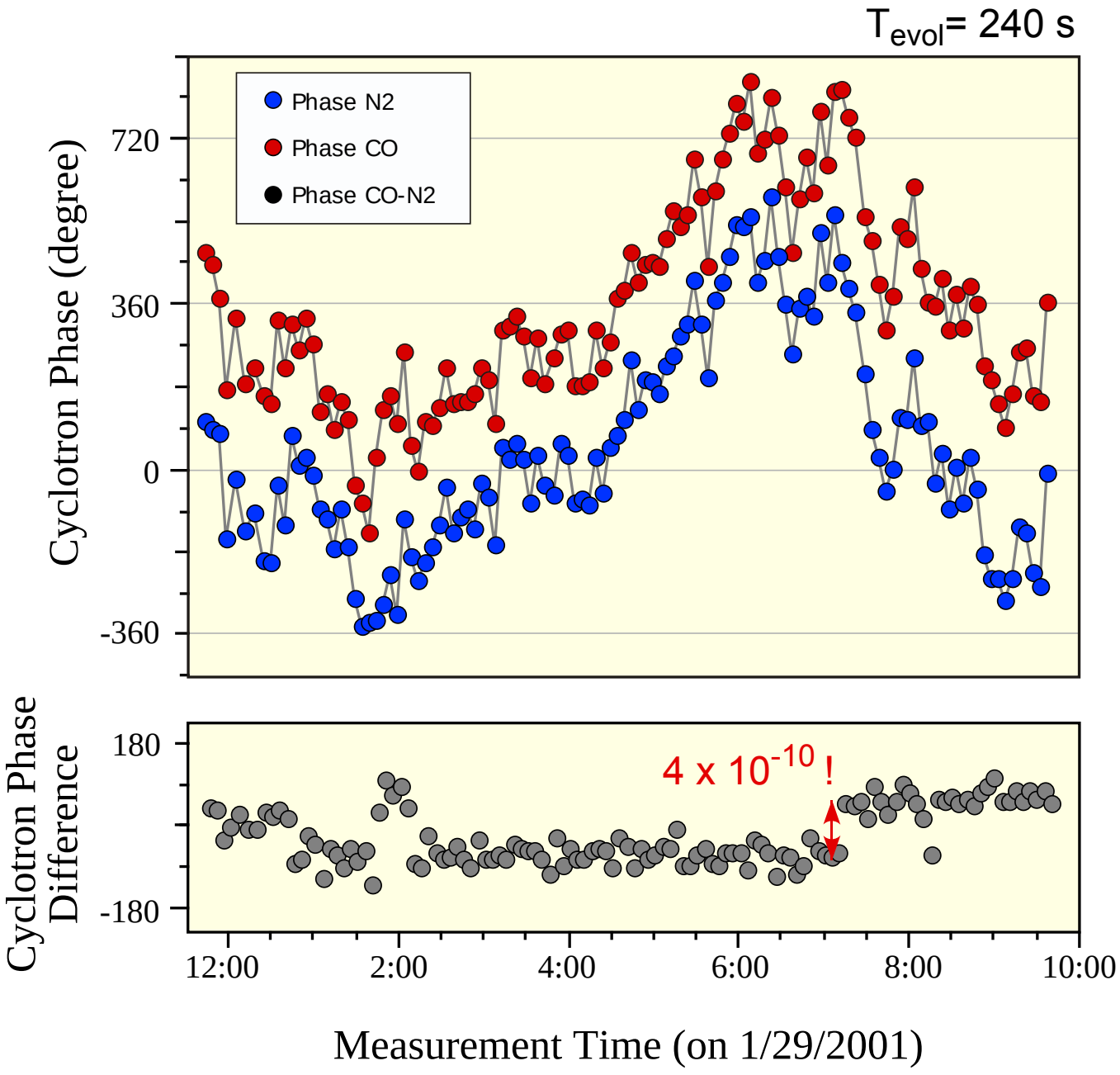
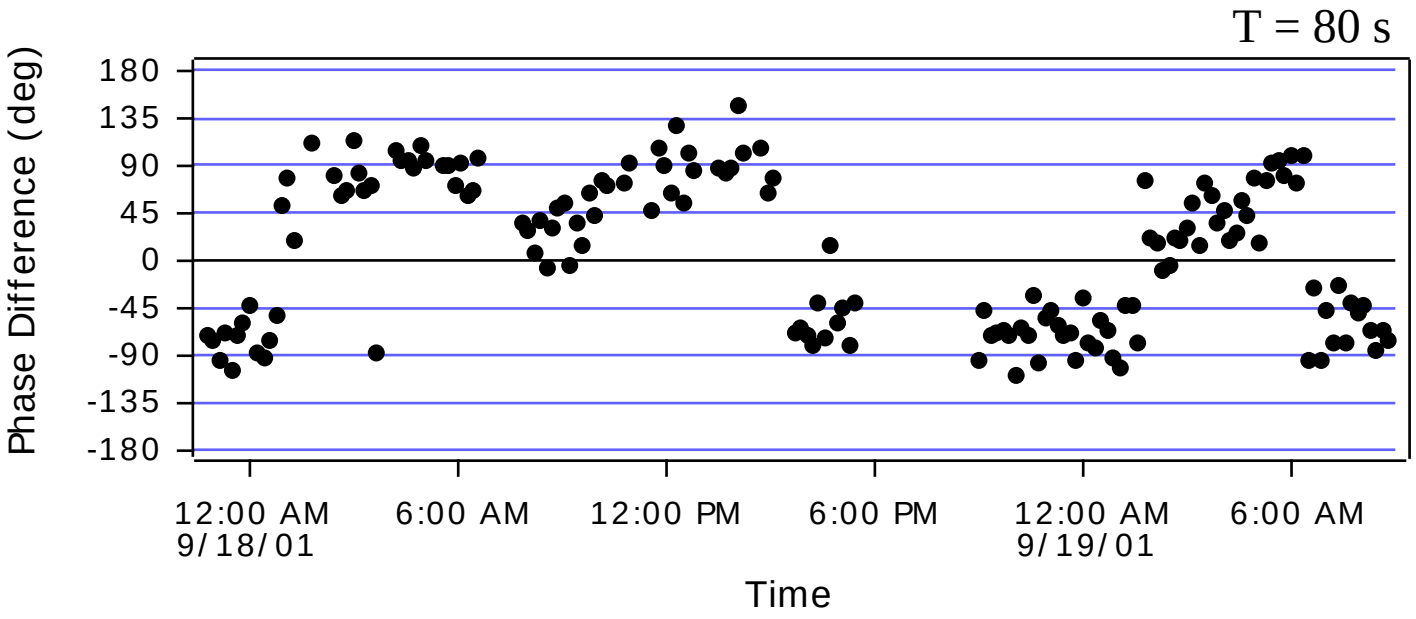
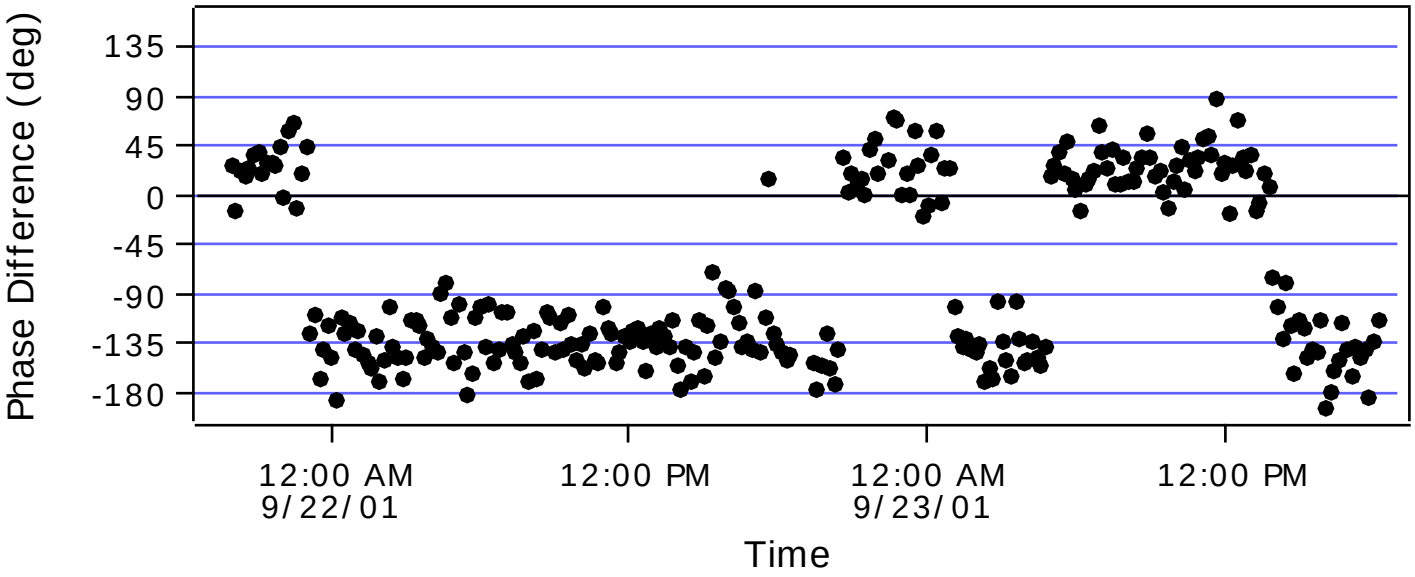
Simultaneous Cyclotron Frequency Measurements

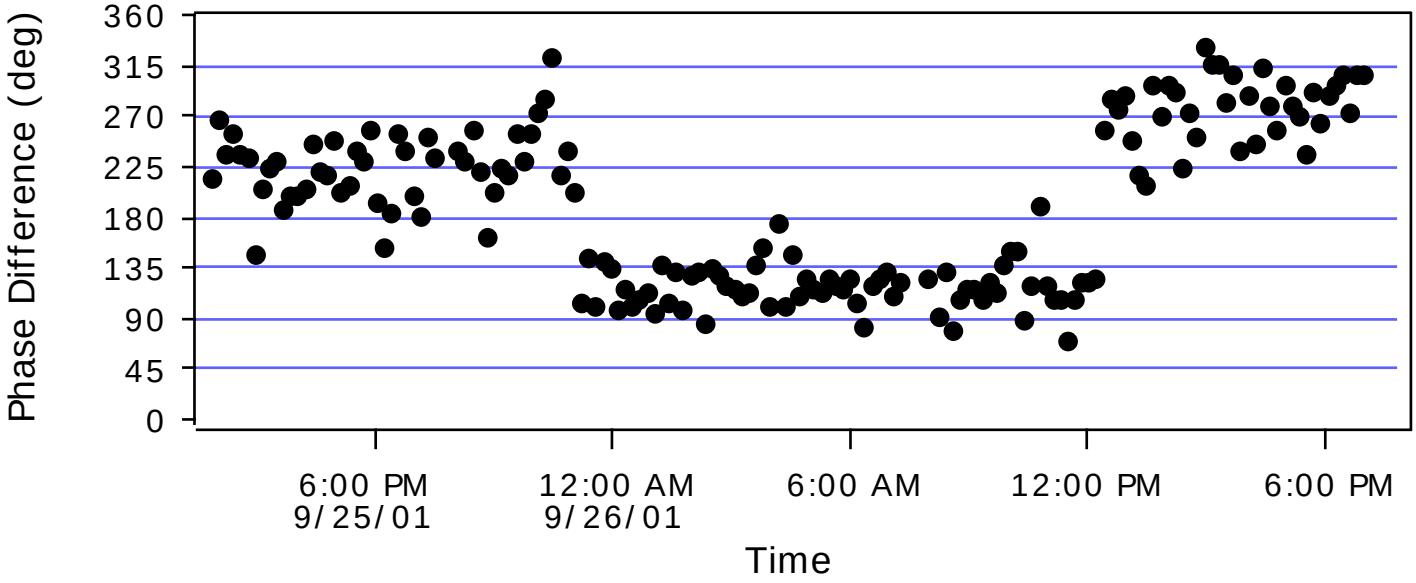


Big Jumps in Phase Difference !

Recurring Problem





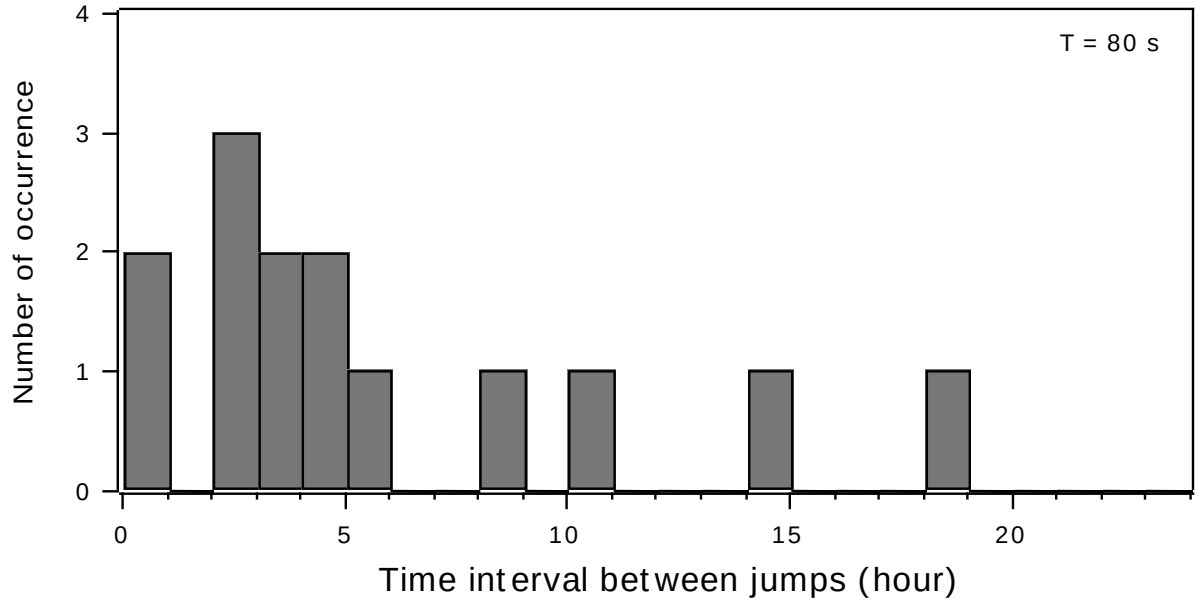


Characteristics of Phase Jumps

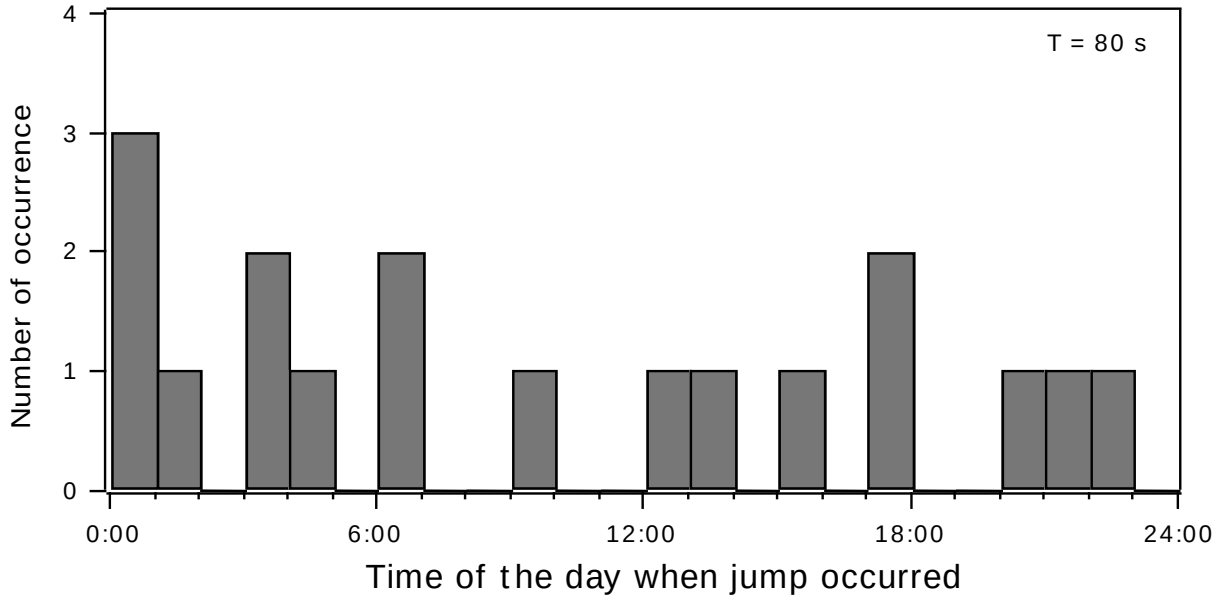
We've observed ~ 20 jumps in 110 hours of data.

1) Not Periodic

shortest : 10 minutes
longest : 21 hours

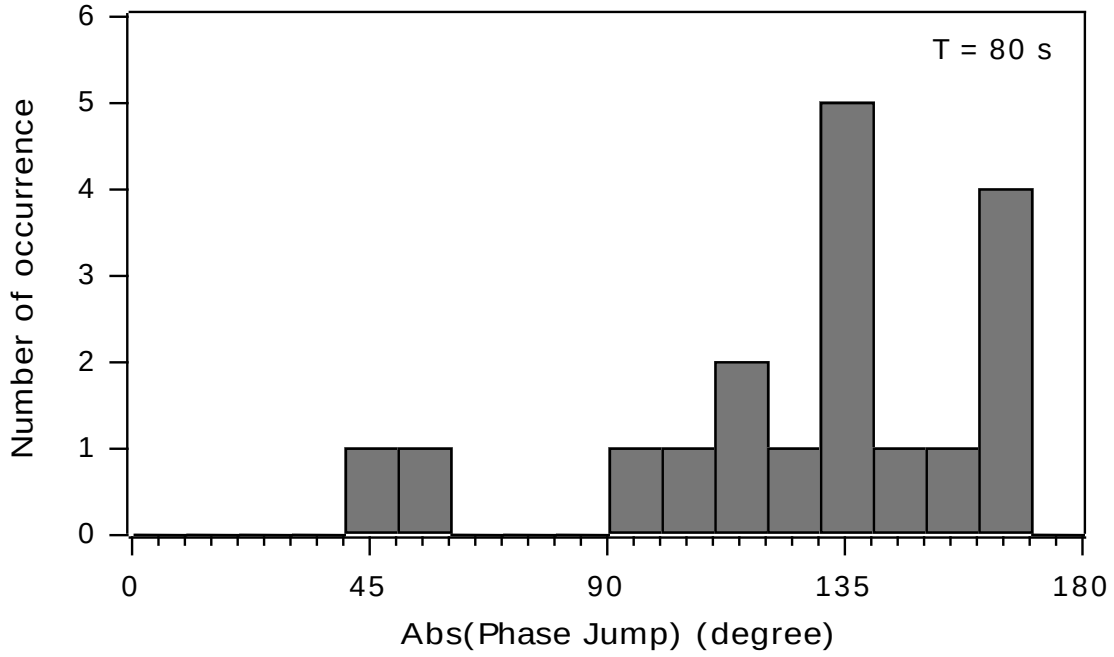


2) Do not occur at a fixed time of the day



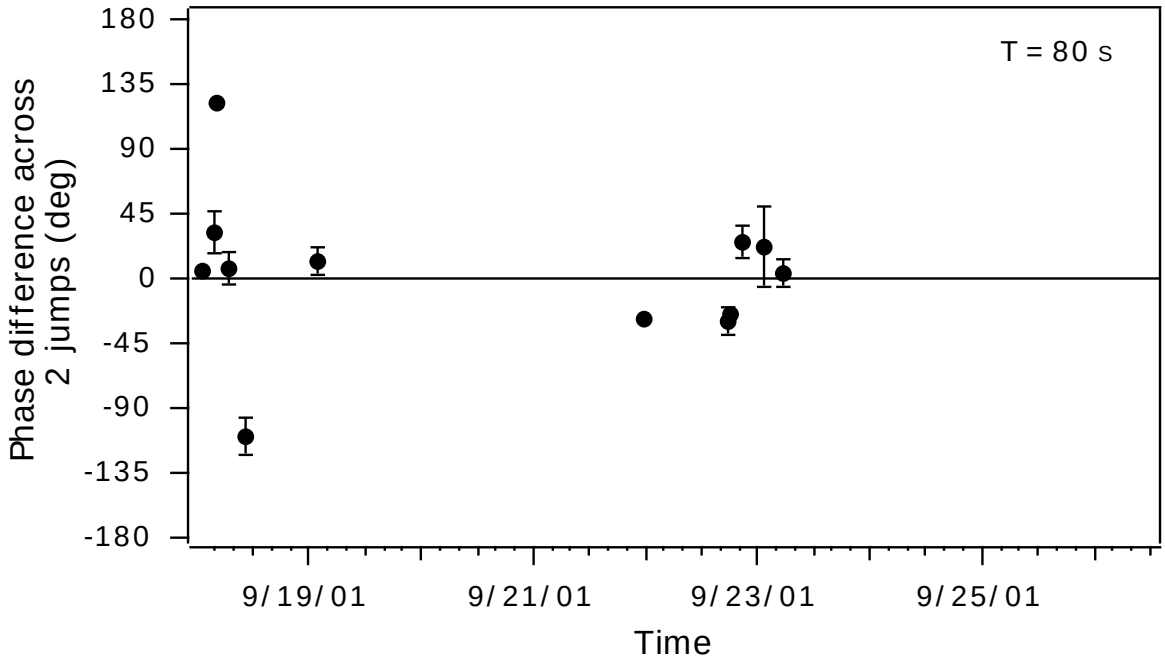
Characteristics of Phase Jumps...

3) phase jump = 130 (9)˚ = 0.97 (7) ppb



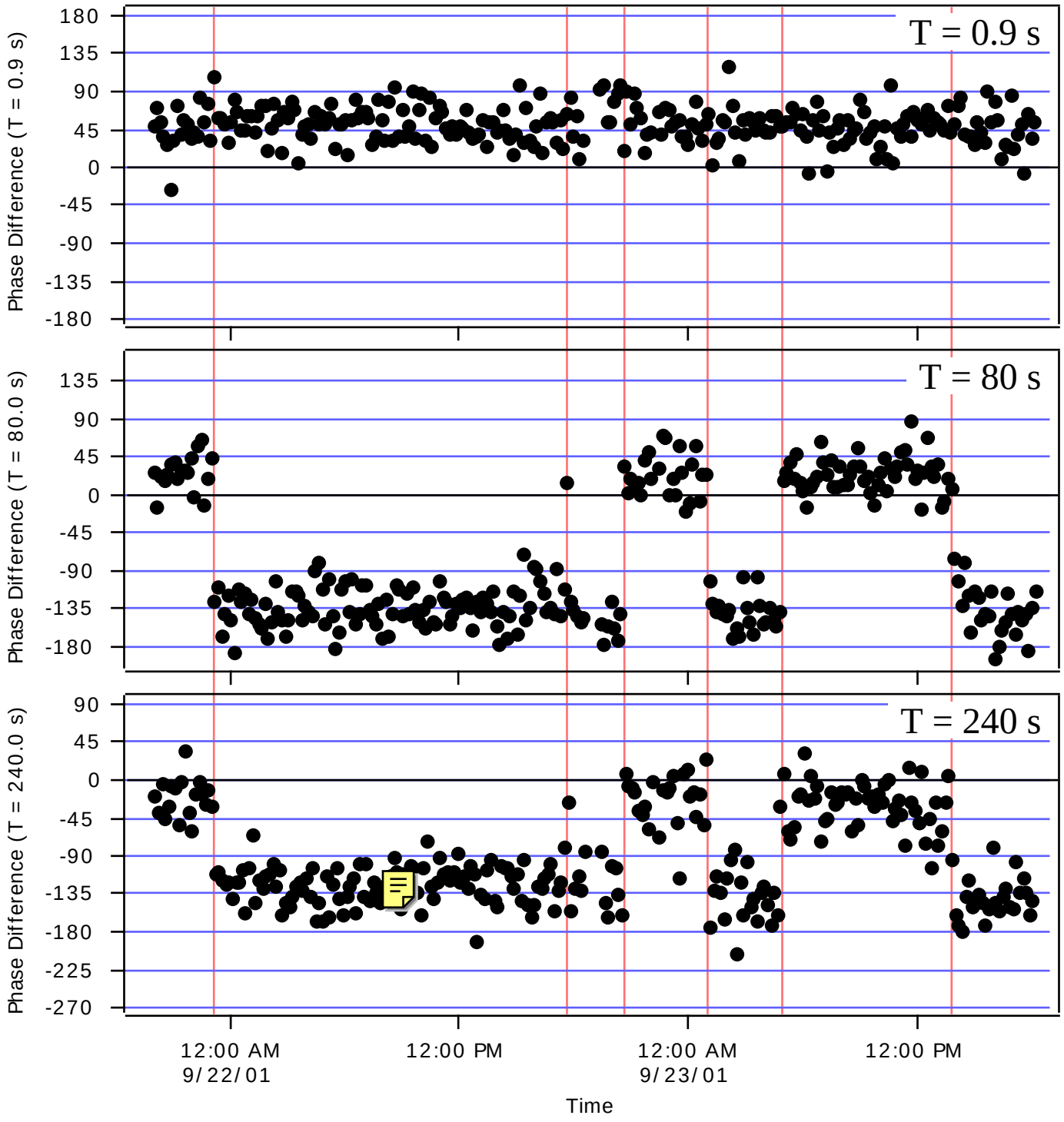
4) "Bistable" behavior:

Phase "comes back" within 35 (11)˚ = 2.6 (8) x 10^{-10}.



Characteristics of Phase Jumps...

5) Look like a frequency shift



Phase jump is proportional to evolution time T

Possible Causes

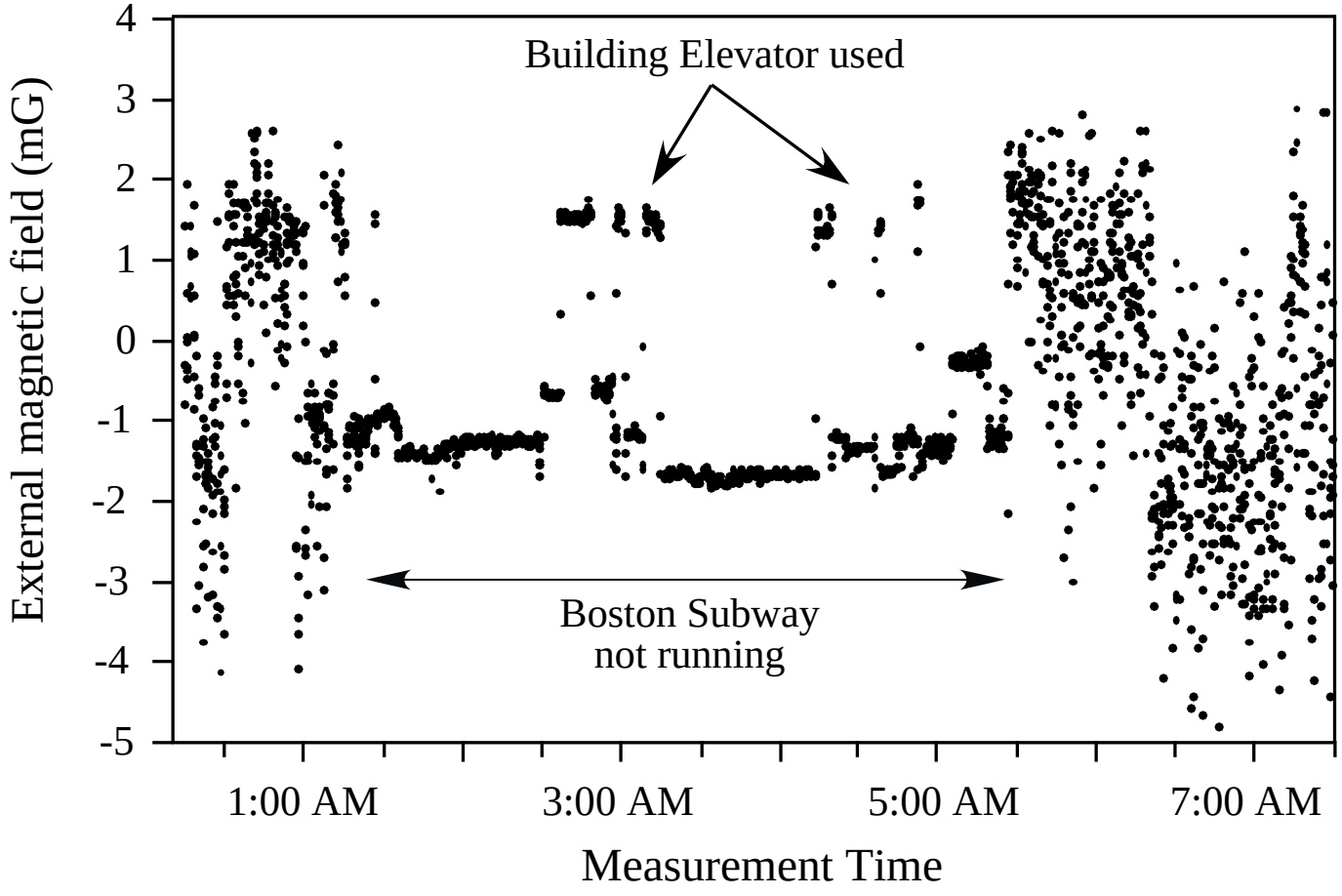
1) Technical problems:

- Really bad frequency reference
- Coupling leakage
- Other ions in the trap

2) Magnetic field jump:

- Need B field to jump by 2.5 x 10^{-6} (200 mG) to explain 1 ppb jump in difference.

! Would result in 11 Hz shift in coupling frequency !



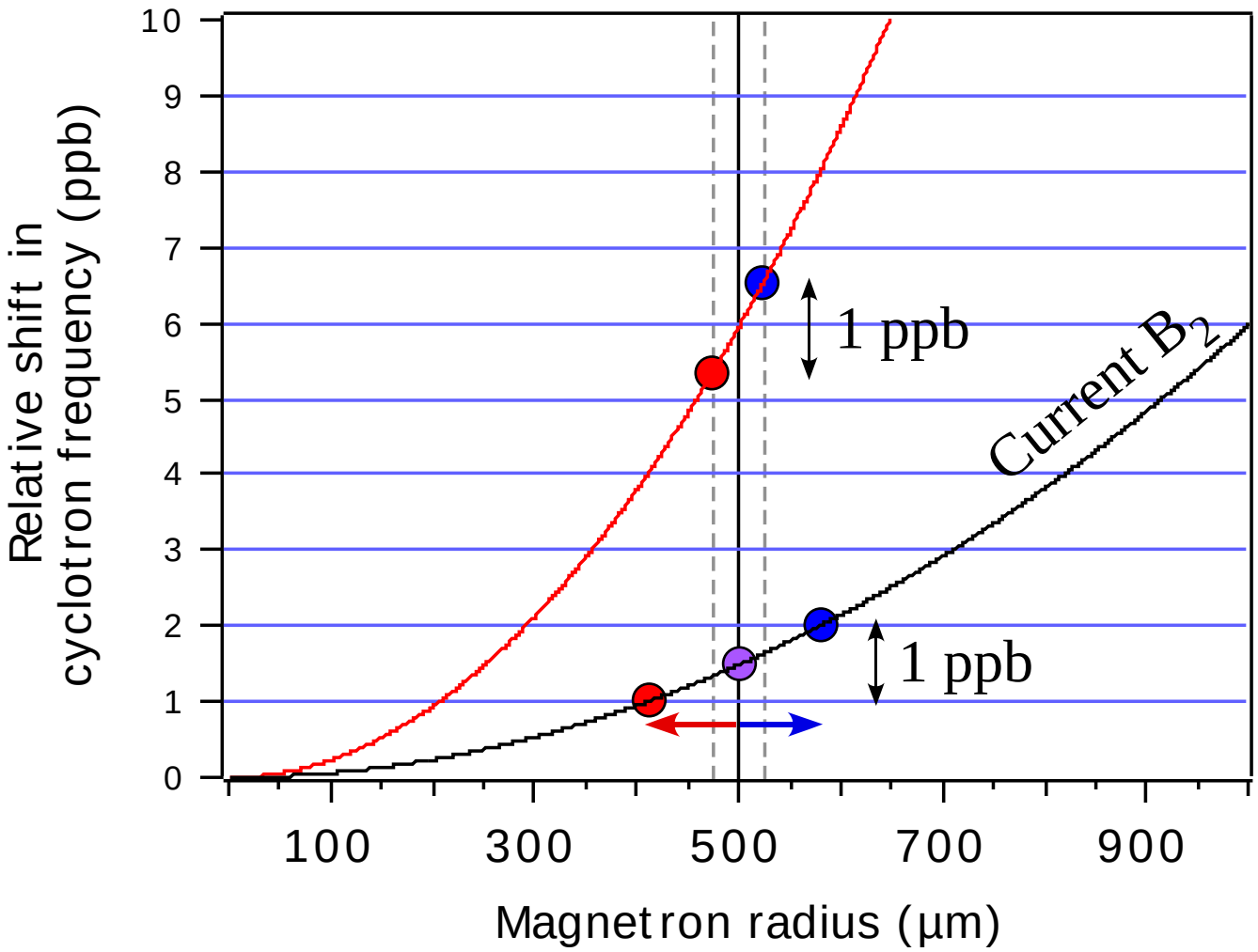
Possible Causes...

3) Trapping field imperfections + dynamics

a) Magnetic field inhomogeneities

$$\vec{B}\,\hat{z} = B_0 + B_2\left(z^2 - \frac{\rho^2}{2}\right) + \ldots$$

$$\Delta f_c/f_c = 0.6 \times 10^{-10} \text{ per } (100\ \mu\text{m})^2$$



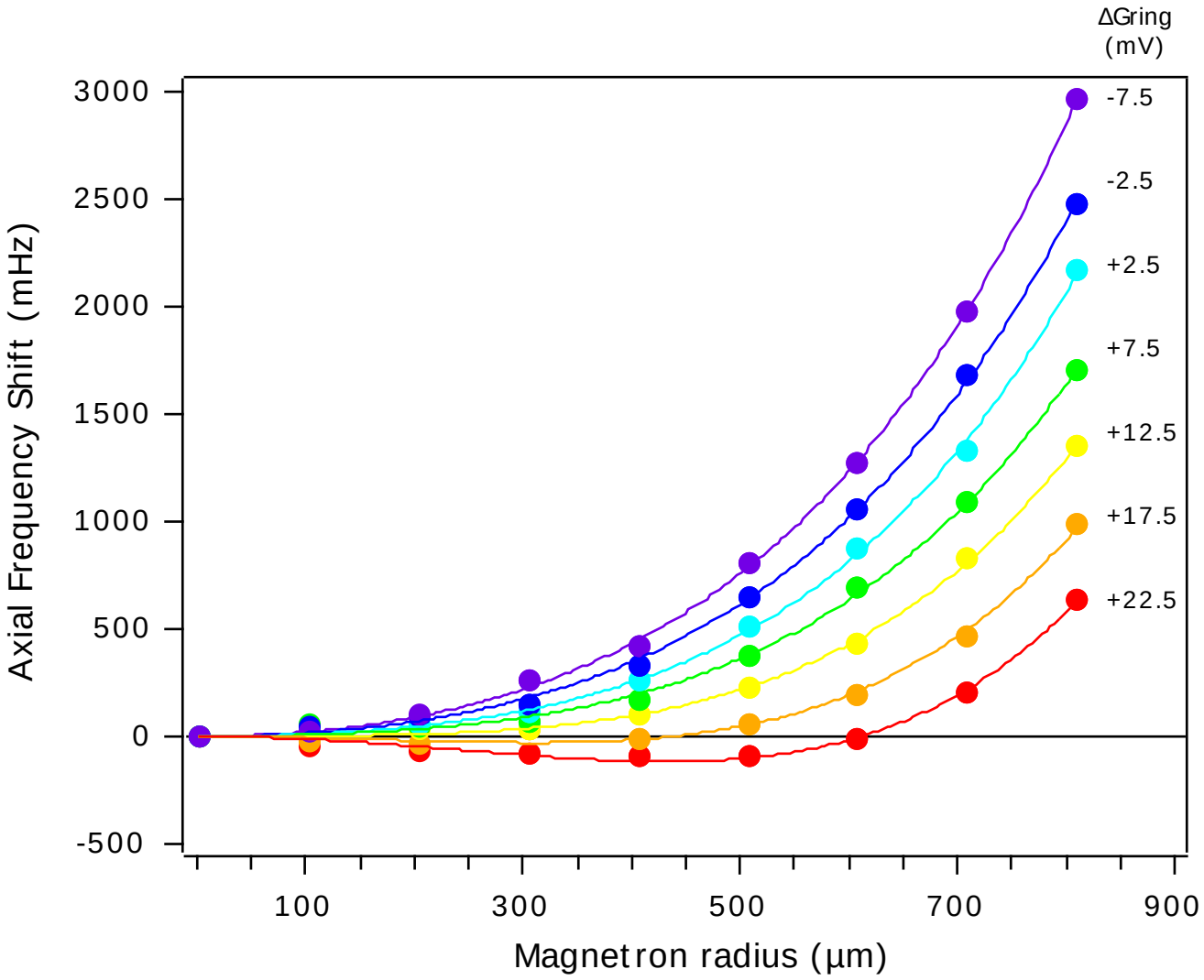
Possible Causes...

3) Trapping field imperfections + dynamics...

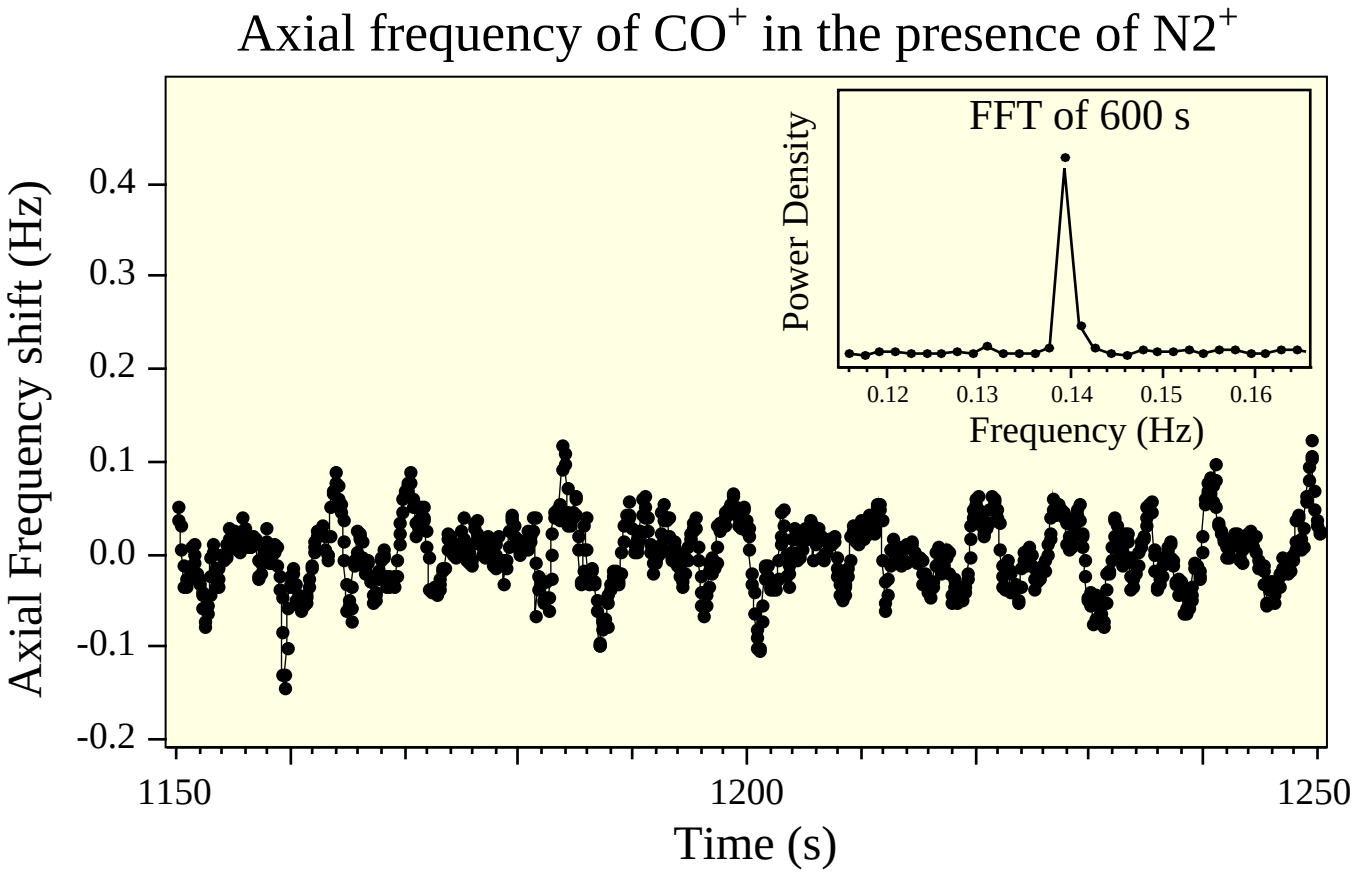
b) Electrostatics anharmonicities

$$\phi = \frac{C_2}{2d^2}\left(z^2 - \frac{\rho^2}{2}\right) + \frac{C_4}{2d^4}\left(z^4 - 3z^2\rho^2 + \frac{3}{8}\rho^4\right) + K$$

Amplitude calibration and new acquisition system
⇒ Measurement of C4 and C6



Watching the Swapping Motion



- Direct observation of swapping frequency.
- Period of oscillation (T_{osc}~ 15 s) matches calculation from estimated separation from make.
- $T_{osc} \sim \rho_{sep}^{3}$

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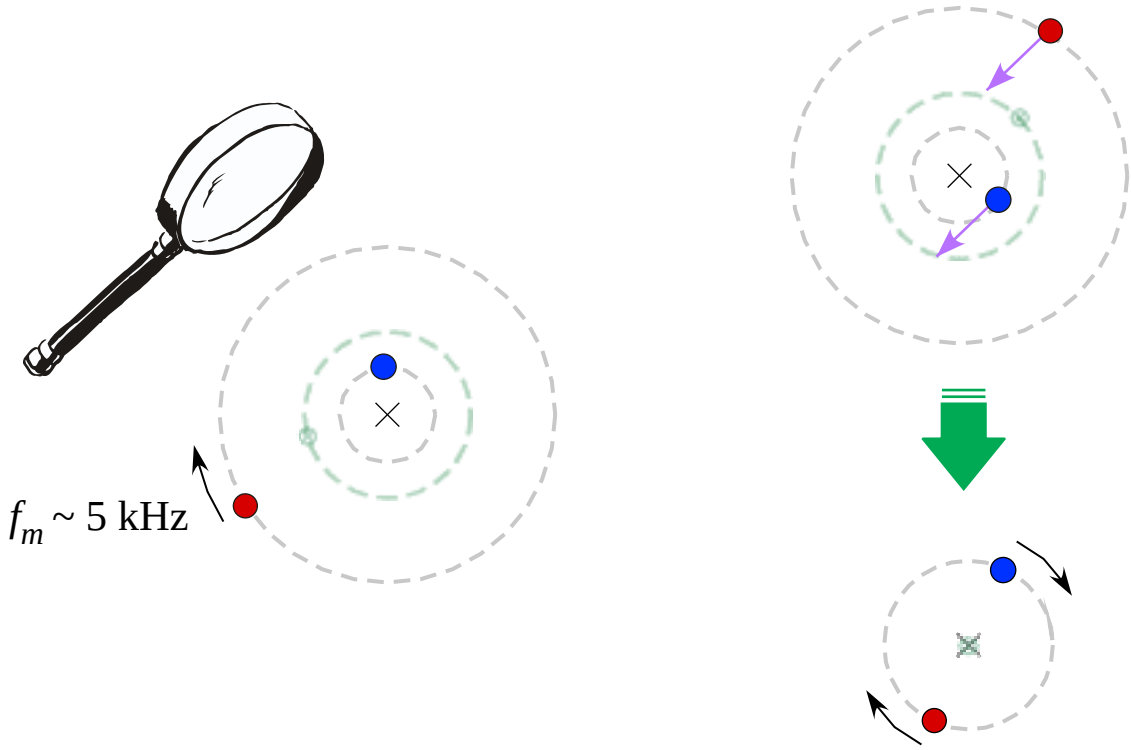
Observed no change in oscillation period and amplitude across a jump in the phase.

What do we do next ?

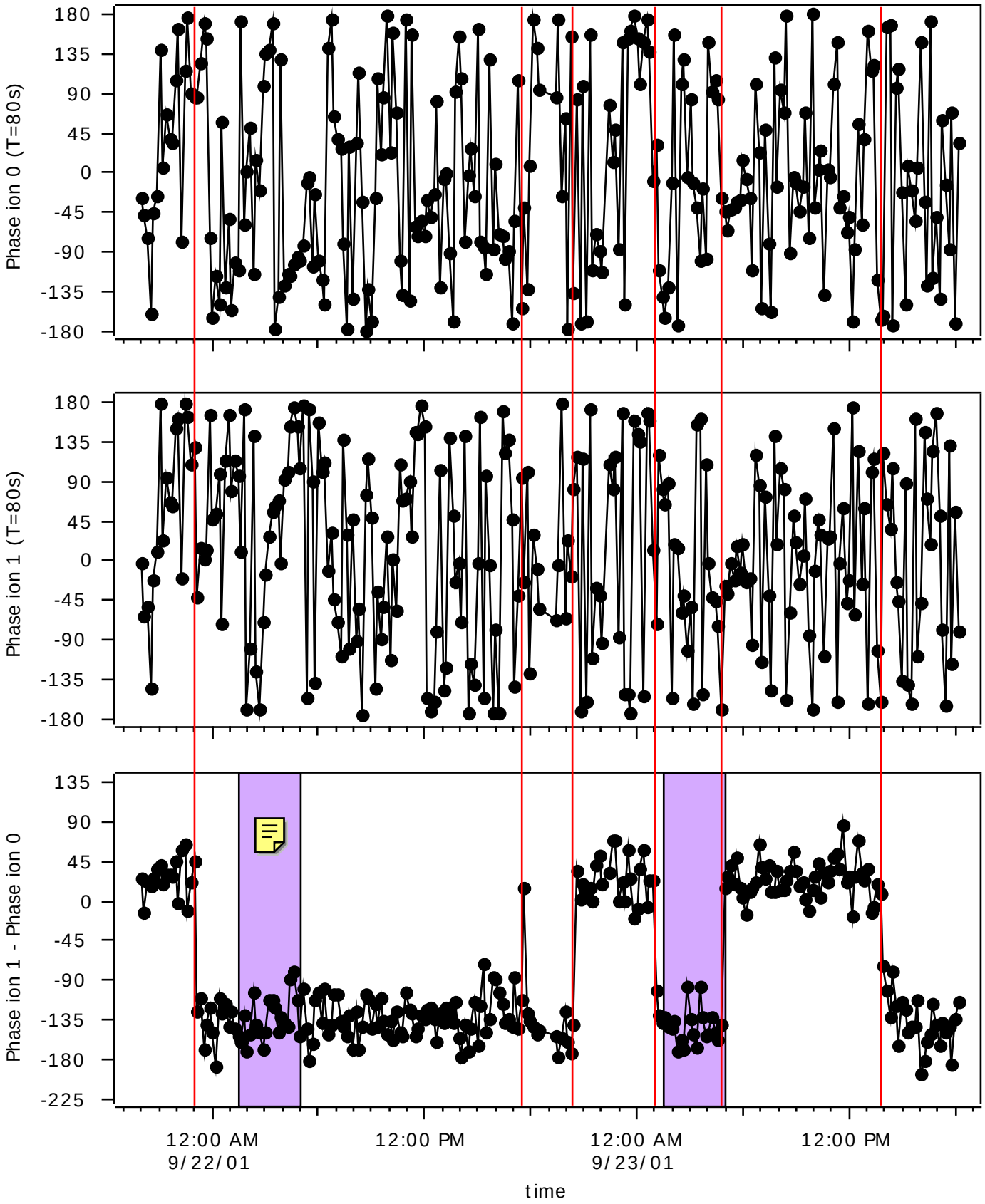
- Measure f_z vs Guard Ring ρ_{mag}
- Study size of jump vs separation and ρ_{cyc}
- “Measure-and-Zero” Technique:



- Try with a different pair
- Modify apparatus to control C_6

Once problem is solved:

- N_2^+/CO^+ to study systematic errors
- $^{32}S/^{33}S$ and $^3H/^3He$
- chemical binding energies ?


Phase ion 0 (T=80s)
180
135
90
45
0
-45
-90
-135
-180
Phase ion 1 (T=80s)
180
135
90
45
0
-45
-90
-135
-180
Phase ion 1 - Phase ion 0
135
90
45
0
-45
-90
-135
-180
-225
12:00 AM
9/22/01
12:00 PM
12:00 AM
9/23/01
12:00 PM
time