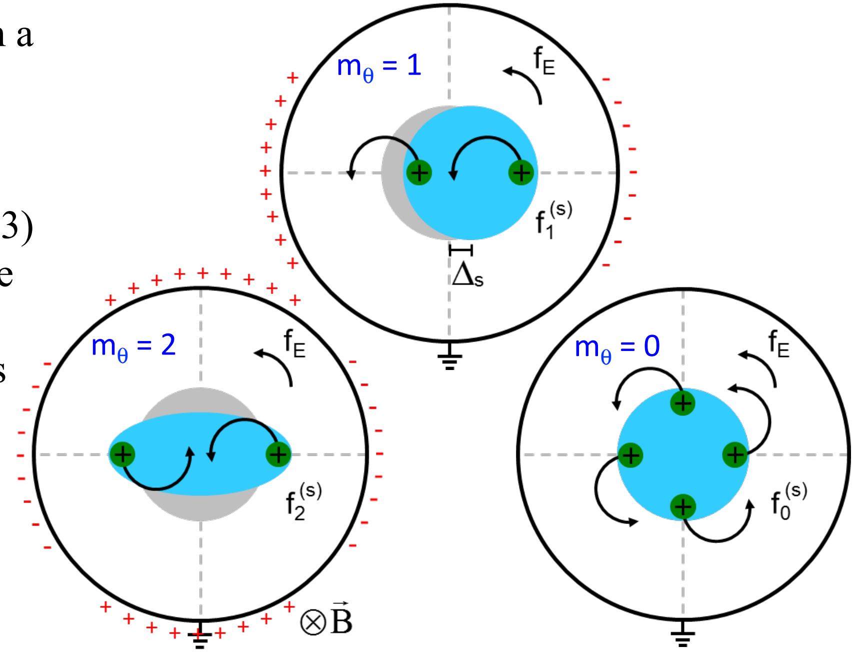
Driscoll/Dubin/O'Neil, UCSD

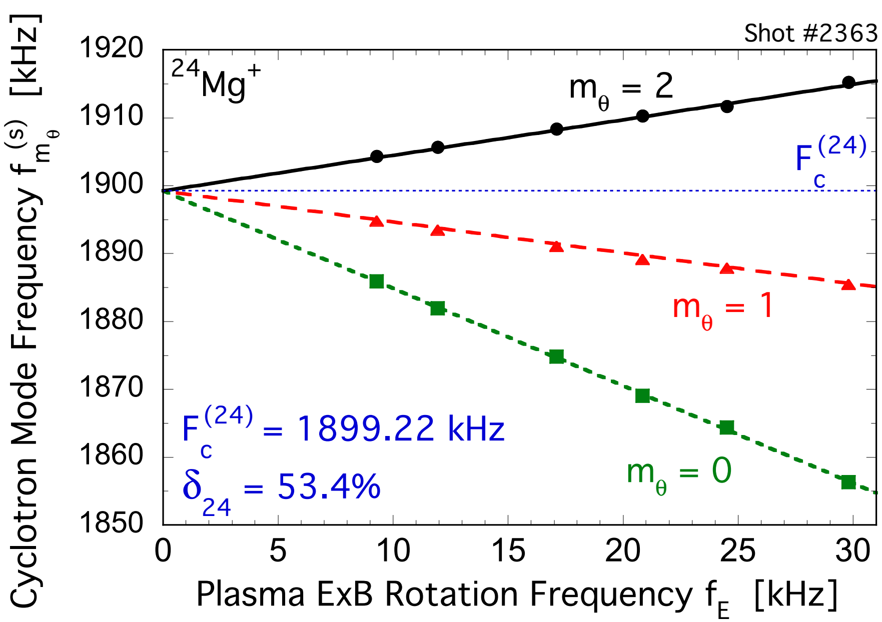
Cyclotron Modes in Multispecies Ion Plasmas

Plasmas exhibit a variety of cyclotron modes, which are used in a broad range of devices to manipulate and diagnose charged particles. However, plasma electric fields shift the mode frequencies away from the "bare" cyclotron frequencies $2\pi F_c^{(s)} = q_s B/M_s$ for each species s. Theory analysis (Dubin 2013) for un-neutralized ion plasmas gives precise predictions of these shifts for the "regular" $m_\theta = 1$ (center-of-mass) mode, for the unusual $m_\theta = 2$ mode, and for the novel $m_\theta = 0$ mode, which has no radial electric field (cartoons shown). For a species of fraction δ_s, the frequency shift is given by

$$f_{m_\theta}^{(s)} - F_c^{(s)} = \left[\left(m_\theta - 2\right) + \delta_s\left(1 - R\right)\right] f_E ,$$

where f_E is the ExB drift rotation frequency, and R represents a small image charge correction from the conducting wall.





A new laser-thermal cyclotron spectroscopy technique (Affolter 2014) gives the first quantitative measurements of these shifts. The figure shows frequency measurements of the $m_\theta = 0$, 1, and 2 modes for $^{24}Mg^+$. A theory fit to the data shown gives $F_c^{(24)}$ to an accuracy of 2 parts in 10^4, and determines the species fraction and in-plasma electric field to high accuracy. These new results are relevant to "space charge" and "amplitude" calibrations for cyclotron mass spectroscopy devices widely used in molecular chemistry and biology.

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D.H.E. Dubin, Phys. Plasmas, **20**, 04120 (2013)