# A new generation $^{27}Al^{+}$ optical clock

Daniel A. Rodriguez Castillo[1,2], Willa Dworschack[1,2], Mason Marshall[1], David B. Hume[1,2]

[1]Ion Storage Group, National Institute of Standards and Technology, Boulder, CO
[2]Physics Department, University of Colorado, Boulder, CO

Email: david.hume@nist.gov

The $^{1}S_0$ to $^{3}P_0$ transition of $^{27}Al^{+}$ has been shown to be an excellent frequency standard due to its narrow intrinsic linewidth and low sensitivity to external fields. At NIST, the previous generation of this $Al^{+}$ clock was shown to have systematic uncertainty below $1x10^{-18}$ [1]. A network of optical clocks in Boulder including $^{27}Al^{+}$, $^{171}Yb$ and $^{87}Sr$ has measured frequency ratios with a total uncertainty between $6x10^{-18}$ and $8x10^{-18}$ [2].

The next generation $^{27}Al^{+}$ clock is under evaluation at NIST and is expected to improve on both these results. The new design facilitates trapping multiple Al+ ions and taking advantage of the improved projection noise. Improvements include reduced excess micromotion and lower background gas pressure. Fig. 1 shows a measurement of the two-ion crystal reordering rate caused by background gas collisions. The reordering rate of ~1 event/hour is consistent with an upper bound for background pressure of $5x10^{-12}$ Torr, which is a factor of 30 lower than the previous generation.

Progress towards a multi-ion clock as well as towards a full systematic characterization of the single ion apparatus will be presented, the latter done with the goal of repeating the clock network measurement campaign.

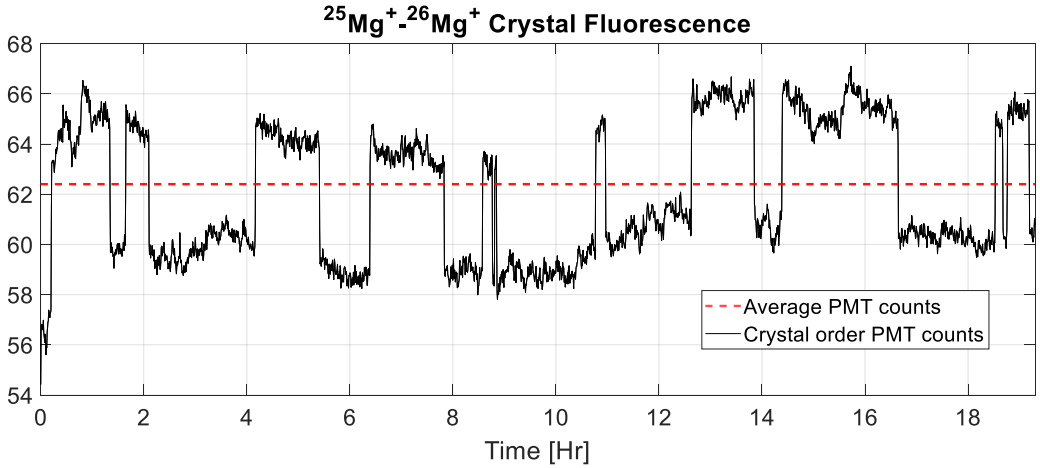


Fig. 1: Order-dependent fluorescence counts of 25Mg+ and a dark ion in the new trap environment.

[1] Brewer, Samuel M., et al. "$^{27}Al^{+}$ quantum-logic clock with a systematic uncertainty below $10^{-18}$." Physical Review Letters 123.3 (2019): 033201.

[2] Collaboration, Boulder Atomic Clock Optical Network BACON. "Frequency ratio measurements at 18-digit accuracy using an optical clock network." Nature 591.7851 (2021): 564-569.