Bureau International des Poids et Mesures

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RECOMMENDED VALUES OF STANDARD FREQUENCIES FOR APPLICATIONS INCLUDING THE PRACTICAL REALIZATION OF THE METRE AND SECONDARY REPRESENTATIONS OF THE DEFINITION OF THE SECOND

ALUMINIUM 27 ION ($f \approx 1121$ THz)

$^{27}Al^+$ ion, $3s^2\ ^1S_0 - 3s3p\ ^3P_0$ unperturbed optical transition

1. Recommended value [1] of the frequency in the CIPM List of Frequencies

$f(^{27}Al^+) = 1\ 121\ 015\ 393\ 207\ 859.16$ Hz

equivalent to

$\lambda(^{27}Al^+) = 267\ 429\ 385.730\ 488\ 67$ fm,

with a relative standard uncertainty of 1.9×10^{-16}.

This radiation was endorsed by the CIPM as a secondary representation of the definition of the second [2].

2. Method to establish the recommended value

A global adjustment of all measurements of frequency ratios published in peer-reviewed publications and available to the CCL-CCTF WGFS was carried out following the methods presented in [3-7].

This adjustment determines the frequency of 14 transitions (see Figure 1) which are either already adopted as secondary representations of the second [7] or considered as candidates for SRS. It took into account 105 measurements, including 33 frequency ratios and 72 absolute frequency measurements (i.e. ratios to the ^{133}Cs frequency). A total of 483 correlations between these input measurements were estimated and considered in the adjustment. More details on the input data and the processing are provided at https://webtai.bipm.org/ftp/pub/tai/publication/wgfs/Adjustment_2021.html . The recommended value is the direct result of the adjustment, rounded as deemed adequate with respect to the recommended uncertainty.

While the results are from a global adjustment, it is of interest to note (see Figure 1) that the $^{27}Al^+$ transition is involved in 2 measurements relative to ^{133}Cs, and in 3 frequency ratios with optical transitions.

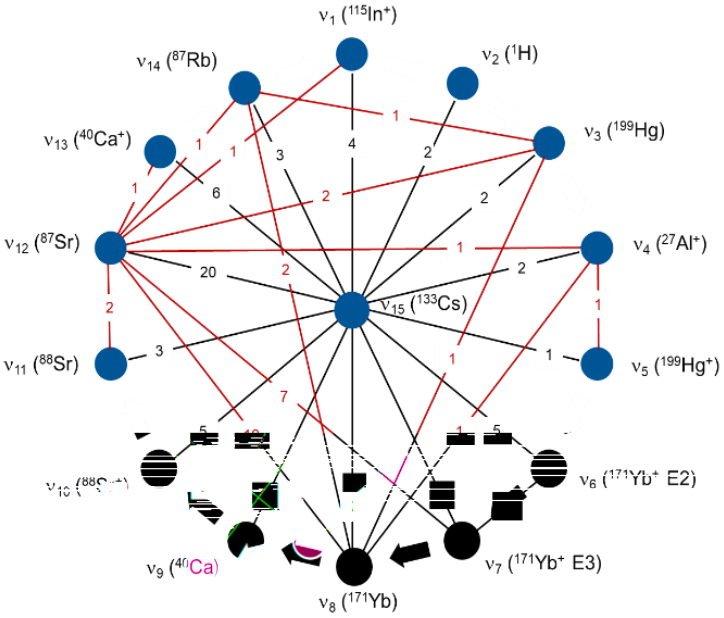

Figure 1: Representation of the 105 measureents linking 14 transitions on the circle and ^{133}Cs at the center.

3. References

[1] Consultative Committee for Time and Frequency (CCTF), 22nd meeting (session II – online), Recommendation PSFS-2 available at https://www.bipm.org/en/committees/cc/cctf/22-_2-2021
[2] CIPM Recommendation 1 (CI-2013) https://www.bipm.org/utils/en/pdf/CIPM/CIPM2013-EN.pdf
[3] H. S. Margolis, P. Gill: Least-squares analysis of clock frequency comparison data to deduce optimized frequency and frequency ratio values; *Metrologia* **52**, 628 (2015)
[4] L. Robertsson: On the evaluation of ultra-high-precision frequency ratio measurements: examining closed loops in a graph theory framework; *Metrologia* **53**, 1272 (2016)
[5] G. Panfilo, communication to the CCL-CCTF WGFS. A new implementation of [4] was realized in MatLab at the BIPM (2020)
[6] Ch. Oates, communication to the CCL-CCTF WGFS. An independent program was developed in Mathematica at NIST (2017)
[7] F. Riehle, P. Gill, F. Arias, L. Robertsson: The CIPM List of Recommended Frequency Standard Values: Guidelines and Procedures; *Metrologia* **55**, 188-200 (2018)