Report on the Meeting of the CODATA Task Group on Fundamental Constants

Monday, 30 August 2015
BIPM, Sèvres, France
Prepared by B. Wood, National Research Council

1. Opening of the meeting and introductions

The meeting opened at 9:30 am Monday morning and introductions were made. Members of the Task Group on Fundamental Constants in attendance were: David Newell (chair), Barry Wood (vice chair), Franco Cabiati, Kenichi Fujii, Savely Karshenboim, Peter Mohr, François Nez, Krzysztof Pachucki and Terry Quinn.

Present as observers were: Martin Milton (BIPM Director), Richard Davis, Michael Stock, Pierre Gournay, Stephan Solve, Nick Fletcher, Hao Fang, Franck Bielsa (all of BIPM), Jifeng Qu (NIM) and Horst Bettin (PTB).

The following sent their regrets: Estefania de Mirandés (BIPM), Joachim Fischer (PTB), Zhang Zhonghua (NIM), Barry Taylor (NIST) and Claudine Thomas.

The chairman, David Newell, opened the meeting with a remembrance of Alain Pickard of the BIPM who recently passed away. Newell commented on Picard's time at NIST and the fact that Alain had participated in many TGFC meetings. Quinn recounted Picard's joining BIPM in 1998 and working in the mass department studying flexure strip mass comparators. Picard represented BIPM on the International Avogadro Cooperation (IAC) and was instrumental in the BIPM watt balance project.

2. Review of the agenda (TGFC15-01)

No additions or modifications were made to the agenda.

3. Review of the report of the Task Group meeting held on Monday, 3 November 2014, at the BIPM

No additions or modifications were made to the report, document TGFC15-02.

Newell discussed the Fundamental Constants Workshop held in Eltville Germany and organized by Karshenboim. The presentations have been

posted on the restricted and public web portals and some of the presentations will be published.

4. Review of the 2014 LSA by technical sub-group.

An overview of these subjects is presented in TGFC-15-03 authored by Barry Taylor.

a. Planck constant *h* and N_A

Wood gave a presentation, TGFC15-04, on the status of the watt balance projects. He also described the NIST consolidation of its previous 2007 and 2014 results.

Fujii gave a presentation, TGFC15-05, concerning developments of the Avogadro projects. It included molar mass, lattice parameter, volume, mass and surface characterization measurements. At the end an evaluation of the correlations of the 2011 and 2014 IAC results was presented claiming a correlation of 0.17. The conclusion was an evaluation of the consistency of the IAC (Avogadro) combined result and the NRC and NIST watt balance results.

Bettin gave a presentation TGFC15-06. It detailed the construction of new enriched Si^{28} spheres, the first two of which have been initially polished within 100nm. PTB expects to produce two spheres per year. Wood asked how many of the enriched lamella samples existed for the lattice spacing measurements. The original is at INRIM but a second has been constructed at PTB for their new experiment but it has not yet been measured. PTB plans to participate in the CCM pilot study using its new Si^{28} spheres. Thus it will be independent of NMIJ results.

b. *R* and *k*

Bettin gave a presentation, TGFC15-07, describing progress on the Boltzmann content and prepared by Fischer. The discrepancy of the molar mass of argon gas used at LNE and NPL has now been resolved by measurements made at KRISS. This has resulted in a change of the NPL AGT results by 2.7 ppm. Moldover has lead a group evaluating the correlation of the different acoustic gas thermometry results. This data was shown and discussed.

Qu described progress on the Chinese Johnson Noise Thermometry project and he hopes for a new improved JNT number in 2016.

c. Gravitational constant

Newell reviewed the gravitational constant results (see TGFC15-08) which are essentially unchanged since last year. The three newest results are from BIPM, LENS and UCI. The UCI result was originally three values and an aggregate value was obtained from the weighted mean. The UWash, UZur and UCI results were expanded by 6.3 to achieve a Birge Ratio of about 2.

Quinn stated that by looking at the data it seems that the best approach to reconciling the major discrepancy is to re-examine the JILA and BIPM results. Prof. Speak will visit NIST next year to aid in recommissioned the BIPM apparatus at NIST. This experiment seeks to re-evaluate the system and generate a new result.

Two new experiments are anticipated and hoping for results of order 20 ppm by 2018.

The American National Science Foundation is inviting proposals in this field with money of order 1-2M$ per grant.

d. Alpha

For the 2014 LSA there was a report of a new Cs atomic recoil result but a private communication suggest some problems and this value was not used. There have been some improvements in the theory and the new LKB-14 Rb result incorporates these.

Pachucki has had discussions with K. Blaum about measuring the difference of hydrogen-like lead and boron-like lead each of which can be measured to high accuracy. Experiment could be done in 1-2 years. The applicable QED theory is less well known but could be approached. Pachucki will attempt to estimate the time needed to do such a theory for the next meeting. Mohr, Pachucki and Karshenboim discussed various theoretical issues primarily about the number of loops needed to describe the problem.

It was commented that Gabrielse (Havard) has a new measurement of the anomalous magnetic moment of the positron in development.

e. Proton radius

- **muonic hydrogen**

In 2014 the Task Group decided to separate the muonic hydrogen result from the Rydberg and proton charge radius calculations; essentially treating it separately. Meanwhile the discrepancies for the muonic hydrogen spectroscopy continue to be an issue which many groups are attempting to resolve.

Pachucki pointed out that several muonic hydrogen results agree amongst themselves, but are in disagreement with hydrogen and helium results from scattering and spectroscopy techniques.

Karshenboim indicated that he expected a 2s-4p hydrogen result soon.

The LKB group is pursuing a 1s-3s measurement and expects a paper by the end of the year.

- **e-p scattering**

There are two main e-p scattering 'groups' , one representing the World Data and the other from the university in Mainz (see TGFC15-08). For the 2014 LSA this scattering data was averaged into a single 'electron avg.' data point. This, in combination with the H spectroscopy data yields a proton charge radius of 0.8770(45) fm. The muonic hydrogen yields 0.8409(04) fm.

In general there is agreement between the two e-p data analyses but there remain differences in other aspects, like the magnetic radius.

f. Atomic mass evaluation

Mohr referred to the 2012 Atomic Mass Values. He noted that the LSA lists the ionized or nuclear masses which are corrections of the atomic masses. The analysis has been changed to more directly calculate the ionized masses from the binding energy results (removing some correlations).

For the electron mass, a more accurate carbon g factor has been made. This resulted in a modification in the calculation process to minimize the uncertainty and still incorporate some the correlation effects.

g. Theory of the muon magnetic moment anomaly a_μ(th)

Mohr reviewed the reasoning of not including the theory of the muon magnetic moment anomaly. It was left out again because of disagreement within its theory.

Newell noted that there is a new measurement at Fermi Lab of the muon magnetic moment anomaly.

h. Others?

Pachucki noted that the determination of the magnetic moment of the proton (from K. Blaum's group) has improved by a factor of ten. This connects to other magnetic moments through the NMR frequency and propagates to other nuclei frequencies primarily limited by shielding corrections. This includes things like ^{3}He.

Mohr stated that in regard to the muonium hyperfine splitting there is no substantive changes in the experiment or theory.

5. Publication of 2014 adjustment

This is proceeding. Mohr stated that he expects a draft paper by Christmas.

6. Timeline and publication for 2017 and 2018 adjustments

As usual we anticipate a RMP and a JCPRD publication of the 2018 LSA. It was suggested to check if the RMP publication is actually an open access publication.

The special LSA closing date is July 1, 2017. For this four values (and their uncertainties) will be provided to the CCU and CIPM. It was suggested to publish those values in Metrologia (not RMP, JCPRD) with simplified explanations. This would help make the critical information quickly available to the metrological community. The 2017 special LSA must be run and ready for the CCU meeting in 5 September 2017.

A revised LSA with the fixed values of h, e, k and N_A must be prepared and be ready to post on the day that the new SI is implemented.

7. Dimensionless units

Mohr presented document TGFC15-09 which reviews the ambiguity that can occur when using dimensionless SI units such as angle and the hertz. The

matter will be discussed further at the next CCU meeting and was presented for information to the task group.

Karshenboim asked Mohr how often he gets public complaints about this matter. Mohr responded that it does happen and that they have specific examples.
Fletcher stated that he can see the problem in the Planck constant, J/Hz versus Js.
Davis pointed out that things get difficult for other things like the von Klitzing constant.
Wood pointed out that both the CCU and the CIPM need to approve any such change in the SI.

8. General discussions about alternative analysis techniques

Cabiati gave presentation TGFC15-10 demonstrating the additive expansion process for the 2014 gravitational constant data set, both for individual data points and the set as a whole. He did not did not make a specific proposal or indicate his personal choice

A discussion followed touching on a number of different points. Newell talked about the workshop on uncertainty held at BIPM. Wood stressed that we need a common technique for all the data sets. Davis noted that it would be interesting to try applying the technique to historical gravitational constant data which has been revised over time. Stock noted that different techniques are unlikely to suit different types of discrepancy. Quinn stated that it is important to be seen to use a common technique from LSA to LSA. Milton noted that this problem also occurs in key comparison data but there the tendency is to not use the best recommended value.

It was decided to stay with the established procedure for the next few LSAs. There was no further dissension.

9. Other topics

Fletcher asked if the R_K and J_K tests would be included in the 2014 LSA paper. It was agreed that they will be.

Davis questioned if the new website LSA energy equivalence values have been updated. He felt that they were the previous numbers. Mohr and Newell said that they would look into the matter.

10. Task Group administration

Within CODATA the TGFC is technically no longer a task group, but is now a committee. However this is an administrative convenience for CODATA and it was decided, at least for the present time, to leave the public name unchanged (the CODATA Task Group on Fundamental Constants).

A new task group member was announced; Dr Meng Wang of the Chinese Academy of Science. Dr. Wang heads the Atomic Mass Data Center in Lanzhou China.

11. Date and location of the next Task Group meeting

The date for the next TGFC meeting will be on July 16, 2016, a Saturday in Ottawa, and immediately following CPEM 2016. It was also agreed that there would not be a second meeting in 2016.

12. Adjournment

The meeting was adjourned at 16:15.

DRAFT AGENDA

CODATA Task Group on Fundamental Constants

9:30 a.m. – 4:30 p.m. Monday, 30 August 2015

9:30 a.m. – ? Tuesday, 1 September 2015

BIPM

1. Opening of the meeting and introductions
2. Review of the agenda
3. Review of the report of the Task Group meeting held on Monday, 3 November 2014, at the BIPM
4. Review of the 2014 LSA by technical sub-group
    a. Planck constant h and N_A
    b. R and k
    c. Gravitational constant
    d. Alpha
    e. Proton radius:
    - muonic hydrogen
    - e-p scattering

    f. Atomic mass evaluation
    g. Theory of the muon magnetic moment anomaly a_μ(th)
    h. Others?
5. Publication of 2014 adjustment
6. Timeline and publication for 2017 and 2018 adjustments
7. Dimensionless units
8. General discussions about alternative analysis techniques
9. Other topics?
10. Task Group administration
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