It is my pleasure to write this report on the thesis entitled “Metrology and Many-Body Physics with Ultracold Metastable Helium”, by Jacob Ross. In his thesis, Jacob describes an impressive set of precision metrology experiments with a metastable helium BEC experiment, along with details of experimental progress towards a (now functional) metastable helium BEC machine at ANU. I found the thesis to be meticulously written and easily readable. I appreciated its literary flair, along with clear introductory sections to each chapter, and overall clear structure throughout. The introductory section in particular was excellent. I was also very impressed by the productivity of Jacob’s PhD in terms of publications, especially given the intensive nature of experimental BEC work, and with the large amount of time and effort spent in building/refurbishing the helium lattice experiment.

Below I list a number of (mostly very minor comments, and small typos).

Prologue

1. page 0: Spectrometry --- > spectrometry.
2. page 0: Page numbering starts on “0” instead of “1”, seems odd.
3. page 3: Footnote 3, “Planck” not capitalised.
4. page 11: extra space after He*.

Chapter 1

1. page 17: “Hydrogen”, “Helium” written with caps, should be lowercase.
2. page 26: footnote – “we consider -- Doubly” --> “we consider. Doubly…”.
3. page 28: “coefficiencts” misspelled.
4. page 39: typo in GPE, should be “i \hbar” on left, rather than “-\hbar”.

Chapter 2

1. page 44: “bell-type” --> “Bell-type”.
2. page 44: “413nm” --> “413 nm”.
3. page 50: In the footnote the statement is a bit confusing as worded – it seems to imply that a collimated beam will converge to a focus.
4. page 51: Eq. (2.2), the subscript “lab” should not be italicised.
5. page 53: Missing space between number and unit in “2mm” and “1cm”.
6. page 54: I would add a figure here from the Ref. [108] showing the magnetic coil configuration. Given the other illustrative diagrams in this chapter, it seems out of place to leave out a diagram of the magnetic trapping, especially given its prominence in the later results chapters.
7. page 58: In the footnote, “analogoous” misspelled.
8. page 59: Bad latex reference resulting in “??” partway down the page.
9. page 63: “19.8eV” missing the space before the unit.

Chapter 3

1. page 80: Latex float issue(?) leading to a large space in the page.
2. page 84: similarly, a large space here.

3. Page 88: “One of the most accessible lattice systems to realize with ultracold atoms is the Bose-Hubbard model.” – the wording is strange, just a typo(?) Bose-Hubbard is not a lattice system? Reword.

Chapter 4

1. page 133: I thought that similar to the previous chapter, where the publication is cited, you should mention the arXiv paper here in a footnote. In particular, I thought it necessary to highlight the “equal contributions” of the first and second authors (this could also apply to the original listing of the publication at the beginning of the thesis as well).
2. page 134: “section 5.3gives” missing a space
3. page 136: “We achieve a 20-fold improvement in the precision over the sole previous measurement”. It took me some time to realise that these were earlier results from the same group (although I was familiar with the previous measurement of the tuneout wavelength done at ANU). This should be better highlighted here (it does end up being more transparent in the conclusion chapter).
4. page 141/142: General comment, as above: It would be great to emphasize the experimental improvements that have led to the improvement in this measurement, as it is not very transparent how these measurements are a refinement of the previous ones at ANU. As written, it seems like there is worry that it will make the results of this section appear incremental – but that is the essence of precision measurement anyways, and it is clear from the subsequent sections that a meticulous study was undertaken. This could be done with a few brief sentences in these sections (or on page 136), similar to (but with a bit more detail) to how this is discussed in the conclusion section. As written at the moment, the detail of each of the techniques is well documented, but there is no high-level summary of how these collective improvements that led to the 20-fold improvement in the measurement. As a final comment, the improvement is alternately noted as “25 times” in the conclusion, perhaps this should be consistent throughout.

Chapter 5

1. page 169: “in Tab 5.2” inconsistent with later usage down the page, “table 5.2” and also elsewhere where “Tab. XX” is used.
2. page 173: figure shows power in mW, while the caption describes the powers in Watts. Would modify the figure axis to be consistent.
3. page 181: “smallest precision” to “highest precision”

Chapter 6

1. page 190: section 6.2.1: Throughout this section I was unclear on how the condensate is excluded from the fitting analysis. Perhaps I have missed this, but some clearer explanation is needed.
2. page 208: Figure 6.8: From the text, it appears that these results are from the theory collaborators. They should be attributed in the figure caption.

Bibliography

There are several errors in the bibliography:

1. page 224: Ref. [18], “Bose-einstein”; Ref. [19] “structure of scince”
2. page 227: Ref. [63], “evidence,” should be capitalised, “condesnation”
3. page 236: Refs. [174, 175] duplicate.
4. page 237: Refs. [187, 188] duplicate.
5. page 240: Refs. [229, 230] duplicate.
6. page 241: Ref [237] “87RbD-line” missing space.
7. page 249: Ref. [250], latex typo
8. page 250: Ref. [351], typo “Optics COmmunications”; Ref. [353] formatting issues