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Dear Professor Pegoraro:

I am writing in response to a request by Professor Anna Nobili that I be a reviewer for the thesis of Gian Luca Comandi. I have been very pleased to do this, because I myself have been interested of late in the possibility of using rotors in gravitational tests, which is the main emphasis in this thesis. Following is an evaluation of this thesis.

OVERALL EVALUATION

In reading this thesis I have sought to compare it to those of my own 18 Ph.D. students, and to those of the many other Ph.D. students (both in the USA and abroad) whose thesis committees I have been a member of. (By now this number is several dozen.) I would rate this thesis as one of the best I have read, particularly from the point of view of its thoroughness and attention to detail. There is no question in my mind that Gian Luca's thesis would justify the awarding of a Ph.D. at any university in the United States. Specific comments now follow.

Chapter 1

Since I have been personally interested in the behavior of rotors, I was especially interested in the general discussion of rotors and their instabilities. The main feature of rotors which has made them the objects of some interest, is the self-centering behavior in supercritical rotation, which is throughly discussed in this chapter. Although much of this material is in the literature, this is an excellent summary which I found personally very readable and useful. This summary makes it clear that Gian Luca has a deep understanding of the subject.

Chapter 2

This chapter explains the concept of GGG experiment, which is a differential experiment aimed at testing the Weak Equivalence Principle (WEP) which is the Universality of Free Fall. As Gian Luca notes deviations from the WEP can be characterized by a dimensionless parameter η which is already known to be less than $\approx 10^{-12}$. Various theoretical predictions suggest possible violation at the level $\eta \approx 10^{-13}$-10^{-17}, but for a variety of reasons these sensitivity levels could only be achieved in space. This is the motivation of the GG (space-based) experiment and of GGG, which is a full-scale ground based prototype of GG and which is the focus of this thesis. In the text following Eq.(2.7) on p. 47, the author states the objective of reaching $\eta = 10^{-13}$, for a test of WEP in the gravitational field of the Sun. This would be a significant achievement, especially if theories predicting an effect at this level turn out to be correct. In any case, setting the stage for a test of $\eta \approx 10^{-17}$ in GGG is in itself extremely important. As noted by the author at the top of p. 45, supercritical rotation allows modulation of any expected signal at high frequency, and results in reduction of $1/f$ noise, as well as electrical and mechanical noise.

This chapter also contains an excellent discussion of the effects of seismic noise, which is a major concern for all terrestrial experiments. As noted by the author, this is one motivation for the space-based GG experiment, where such effects would not be present. I feel that the discussion on pp. 58-59 of the effects of terrain tilts is excellent, (particularly the emphasis on p. 59 that “...local terrain tilts cannot be distinguished from horizontal disturbing accelerations.")

Chapter 3

This chapter presents a detailed mathematical model of the GGG system. I found this chapter to be fascinating in that the author was able to model GGG sufficiently well so as to achieve the argeement between theory and experiment exhibited in Fig. 3.3. This figure also exhibits the two branches of normal modes, as discussed on p. 81. Again a very impressive combination of theory and experiment.

Chapter 4

This chapter discusses an analysis of the dynamical response of the GGG differential accelerometer, and demonstrates that the common mode registers and the self-centering can be appropriately controlled.

Chapters 5-7

These are essentially experimental chapters, which I as a theorist am not expert enough to evaluate. I have nonetheless read through them, and I have no specific comments.

Chapter 8

This gives a coherent summary of GGG. From my viewpoint the key points made here are that the GGG system can in fact be controlled so as to achieve the target value $\eta=10^{-13}$. This includes controlling the self-centering to the requisite level. That one can achieve this goal is impressive, and is conveyed in part by Figs. (4.7),(4.8), and (4.17).

This chapter has some useful—if sobering—numbers. As noted on p. 164, they have managed to reduce the separations of the centers-of-mass of the test cylinders to 0.1 μm, which is itself a heroic feat. However, this only achieves a level $\eta<10^{-7}$ compared to the target value $\eta<10^{-13}$. This suggests that GGG needs to be improved by $\sim 10^{6}$ to achieve the target level. In my view this is one of the major achievements of this thesis—providing some hard results which will hopefully guide the future development of GGG.

Chapter 9

This chapter builds on the previous results and discusses the actual space-based experiment, GGG. Figures 9.1-9.3 give the conceptual design of the experiment and the motivation for going into space (see previous remarks). This is an extremely detailed analysis which is quite thorough. It is quite clear that Gian Luca (and Professor Nobili) have worried about many details—too numerous to enumerate here.

Summary

As I stated at the outset, this is one of the most impressive Ph.D. theses I have seen among the several dozen that I have read over the years. This would rank near the top in any university in the United States. It is a great credit to Gian Luca Comandi and to Professor Nobili that they have put together such an impressive piece of work. For my part I have learned a great deal from reading this, and I intend to keep it handy as a reference on rotors.

If I can be of any further help I will be glad to do so.

Sincerely,

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