MORIOND SUMMARY TALK

JAMES E. FALLER

JILA, University of Colorado and National Institute of Standards and Technology,
Boulder, Colorado, 80309-0440, USA

I attempt to point out some of the highlights of this Moriond Conference on Gravitational Waves and Experimental Gravity. At the same time, I try to evidence something of the character of this meeting.

Moriond Workshops are akin to confessional booths. Those in attendance freely confess their "sins" (admit to not knowing exactly how to proceed) while putting forth new and better ideas for both theory and experiment. The means for absolution is received in the form of comments, criticisms, and suggestions that are spontaneously given by the various participants as they listen to each of our confessions. This confessional booth ambience results in lively, open, and useful exchanges that begin each day at breakfast and continue through lunch and dinner until late at night. It is this spirit of freely exchanging ideas that makes these conferences enjoyable and scientifically productive!

As is always the case, the quality of a meeting depends on who's there. Waiting in Geneva for the conference bus to take us to La Thuile, it became clear, based on the participants who were gathering, that this Recontres de Moriond devoted to Gravitational Waves and Experimental Gravity would be a very interesting meeting.

Though gravitational physics is one of the oldest areas of science, it is nevertheless a subject that in recent years has come of age. Today's experimental techniques and capabilities are (or nearly are) capable of measuring for the first time at the levels of precision needed to see many of gravity's more subtle effects. Gravity, "a property of bodies perceptible to the vulgar when things fall to the ground, but long acknowledged by this Society to be a quality impressed by the Creator on all matter..." (John Pringle in his 1775 address to the Royal Society), is still far from being
understood. Not only are many of its effects extremely weak (and therefore almost impossible to measure), but "gravity" still remains disconnected from the rest of Nature's forces.

Twenty years ago, I believe that there were more theoretical than experimental papers written on the various aspects of gravity. Today, it is probably just the opposite. Gravity has come of age as a result of today's measurement techniques and our ability to use space as a quiet and unperturbed laboratory. Gravitational physics has accordingly evolved from a largely theoretical subject to one in which heroic experimental methods are being devised and fairly large groups have been marshaled together to embark on experiments to let us see and measure gravity. Papers written by a small number of authors have, in recent times, been joined by (a few) papers with literally hundreds of authors — each (presumably) having contributed some critical aspect to what in part has become (I think by necessity) large science. In spite of this growth in group and program size, gravitational physics is still a field driven by the ideas and insights of a few creative minds — as well as by late night discussions at meetings such as this one.

One important — and delightful — aspect of this meeting was the number of young scientists who were able to attend, thanks in part to support being made available for young scientists by the European Union.

So what was the meeting about? The topics covered included: theoretical, analytical, and numerical modeling of sources for gravitational waves; present and future detector development for bars on the ground and interferometers both on the ground and in space; experimental gravity involving the use of ultrastable clocks for high precision tests of fundamental physics, matter wave sensors, discussions related to the ultimate limits in quantum measurements, and tests of the equivalence principle; precision gravitational metrology including fundamental constants and their possible variation; and finally, new gravitational theories. "Traditional" gravitational experiments included measurements of G as well as both atom-based and optical interferometer-based freefall determinations of g. In addition to dropping corner cubes (traditional gravimeter) and atoms (cold atom gravimeter), we heard about "dropping" neutrons in order to set new limits on scalar and pseudoscalar forces.

A fascinating (but not overwhelming) subject of discussion involved laser interferometer methods (LIGO, TAMA, GEO, and VIRGO) for the ground-based detection of gravitational waves. The application of "cooling" (as has been traditionally used with Weber-type bar detectors to reduce thermal noise) to long-baseline interferometers (CLIO and LCGT) was also discussed. It is said that the devil is in the details. In the case of gravitational waves, the detection prospects are in the details and critically depend on creativity and cunning being applied to the myriad of details that are associated with these detectors, which represent nothing less than experimental tour de forces. New coatings and substrates for low mechanical loss mirrors, the development of fused-silica ribbon fibers (to hang the mirrors), new interferometer configurations, novel component selection (e.g., gratings rather than beamsplitters), the possible use of "squeezed light" to enhance detector measurement sensitivities, and strategically distributing advanced detectors in a world-wide array would all contribute to "regularly" seeing gravitational waves.

Additionally, the how of seeing waves — strategies for looking for signals buried in huge amounts of data including both analysis methods and (necessary) modeling to know what wave forms to look for — were presented. Quite fascinating papers involving "searches" for gravitational-wave signatures in already existing data were presented. And, in spite of the fact that Nature would have to be terribly kind for them to be successful given today's detector sensitivities, these searches are establishing the necessary frameworks and methods required to extract signals when the detector sensitivities have been upgraded to the point where "theory" assures us that we will see signals.

Three different proposed satellite tests of the equivalence principle (STEP, Microscope, and GG) were described, reminding us that ideas for space experiments, a bit like violets in the springtime, spring up in many places at the same time. Though similar in concept, each of these
experiments was based on a different cost/accuracy tradeoff having been weighed against the probability that the mission would be chosen for flight.

This year's "fifth force" (a subject that was also revisited in several of this year's talks) was the Pioneer anomaly that raised the issue of possible new physics (gravity "pushing" rather than "pulling"). The first task at hand is to (somehow) rule out the possibility that this anomaly is not simply the result of subtle and difficult-to-quantify experimental artifacts. An alternative would be to send another (costly) probe. Nevertheless, just as the many Moriond-based discussions of fifth force experiments were technically fascinating, the thought processes that had been and were being marshaled to see if the new anomaly couldn't (simply) be explained away were quite interesting.

The process of going into every conceivable experimental detail — if not always Physical Review-quality science — serves to expand on our experimental sensitivities. This type of anomaly also reminds us that — other than in text books — more things are known then are actually true. Certainly, experimental gravitational physics requires an appreciation for systematic errors that occur in varying guises in every experiment in which one pushes on technology and experimental sensitivities. The process of acquiring this compendium of experimental awareness is what makes experimental physics fascinating. It also prepares workers in this field for the inevitable question (when gravitational waves are "seen") of "Are you sure?"

The Moriond meeting style — our being willing to talk about problems as well as successes — is critical to our growth as physicists in subjects where there are no easily won battles or advances. The search for gravitational waves stands today as one of the most challenging, demanding, and exciting research areas in physics. Its future path will involve a tortuously long journey where all types of obstacles need to be recognized, then resolved, and finally — using experimental and analytical cunning — solved, cleared out of the way, or (somehow) worked around. In producing an appreciation for and an understanding of the needed wealth of technological innovations, all based on underlying physics, the Moriond format is extremely helpful because it facilitates, through its open discussions, the discovery of routes through and around experimental problems that needed to be solved in spite of their, at first glance, appearing to be insurmountable.

During this meeting, we were also given a status report on the now-completed GP-B mission whose scientific results have been delayed because of "unanticipated experimental problems" (patch charges etc.). The ongoing data reduction, which is trying to work around these various problems, is understandably taking longer than had been anticipated. If there proves to be enough experimental redundancy, the hope is that these effects can be "removed" without (too badly) compromising the science so that this conceptually simple, but technically complex and expensive, space-borne gravitational experiment can pay back the many decades of effort that have been put into this mission.

During the meeting, we also heard about use of atomic clocks in space (as well as in the laboratory) to carry out fundamental tests of physics. Additionally, we were updated on the proposed use of space as a laboratory for low-frequency gravitational wave detection (LISA).

I would like to conclude by thanking the organizers, in particular J. Tran Thanh Van and Jacques Dumarchez for inviting me to participate in this meeting. In the course of renewing old acquaintances and meeting a lot of new people, I learned a number of new "details" that will prove useful in a variety of experiments. For me the meeting was very enjoyable. Given that the purpose of these meetings is to discuss recent developments in contemporary physics and promote effective collaboration between experimentalists and theorists, one would have to say that this meeting was a success. By bringing together a relatively small number of participants, this Moriond meeting helped again to develop better human relations as well as allow for a thorough and detailed discussion of each participant's contributions. As always, we have established new channels of communication. The one possible improvement that occurs to me — were it possible
— would be to find meeting rooms that are broader and less deep which would serve, as with confessionals, to keep the interactions even closer.

I'm certain that I speak for all of the participants when I say that we are all looking forward to the next of these Moriond meetings on Gravitational Waves and Experimental Gravity.