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My Final Report

The aim of my stay at LIGO, on LIGO visitor grant, during the months of April and May 2005, was to contact different people and identify what contributions could my group give to LIGO for the future. Although my appointment is ending on May 31, I will stay two more weeks on my own. During this two-month period I contacted the following groups:

1_ DATA ANALYSIS

Although I would feel comfortable with this activity (I have been working on Solar Data Analysis for several years looking for semi periodic signals buried in noise), I need to devote additional time to understand the LIGO experiment and study the documentation I have collected (for ex the RJD thesis and discussions with Réjean himself, Alessandra Buonanno, Albert Lazzarini and others) before I can formulate a specific plan. To this purpose, I plan to further discuss this topic with my colleagues in Rome, which helped me to perform similar kind of analysis on the solar seismic signals. In particular, I want to clarify with them the usefulness of some techniques that we currently use to recover and identify semi-periodic and discontinue signals buried in our solar and stellar data.

1-REFERENCES

Varadi, F., Pap, J., Ulrich, R., Bertello, L., and Henney, C., 1999, "Searching for Signal in Noise by Random-Lag Singular Spectrum Analysis", AJ, 526, 1052-1061

Varadi, F., Ulrich, R., Bertello, L., and Henney, C., 2000, AJ, 528, L53-56

Bertello, L., Varadi, F., Ulrich, R. K., Henney, C. J., Kosovichev, A. G., Garcia, R. A. and Turck-Chieze, S., 2000, "Identification of solar modes of low angular degree and low radial order", AJ, 537, L143-146

Cacciani A. et al . "A two color pupil imaging method to detect stellar oscillations" Memorie della Società Astronomica Italiana, 2003, Capri meeting on Dome-C in Antarctica

2_ 40 m INTERFEROMETER

I had several meetings at the 40 m interferometer with ALAN, RANA et al, collecting documentation and two thesis (Rana and Matt Evans). Interferometer operations belong to my previous cultural background and instrumental skills. In addition, I had some discussions with HIRO YAMAMOTO on his simulation program and the possible reasons for the instrument instabilities.

All these information converge to identify a consistent proposal for my possible future activity at LIGO, which is, to spend some time (of the order of few months next year) at the sites (40 m and?or the Observatories) to become directly acquainted with the problems of interferometer operations and tuning. As my acquired expertise spans Optics, Spectroscopy and Interferometry, after some discussions with Hiro I rapidily started

going through his simulation program -e2e- with the aim to see how to practically implement some ideas developed during my experience with FPs alignment. To this purpose I can count on people of my group that are expert on C programming , Java and other languages, well compatible with the computing environment used by Hiro. Of course, I need to remain in close contact with Hiro (who showed his kind availability) and somebody else at the instrument sites (and/or the 40 m interferometer).
At the end of the suggested time spent at the site, I could be more specific about ideas for FPs tuning procedures.
2_REFERENCES:
several discussions with Rana, Matt, Hiro Alan and Monica.

3_A TECHNICAL AND OPTICAL LAB (Peter King)
Peter has shown his availability to carry out some laboratory tests on my technology (Magneto-Optical Filter) in view of future possible developments and uses for the general problem of GW detection. This is just a suggestion: to open an activity that could be rewarding later on, both for absolute wavelength reference and/or GWdetection itself (see next paragraph 4-)
3_REFERENCES:
-A.Cacciani et al "Theoretical and Experimental study of a Magneto-Optical Filter" JPL document 1990 and 1994

4_THEORETICAL STUDIES
Connected with the above instrument developments, are two particular problems, among others, that in my view deserve to be studied, that is, the GW induced time dilation and vacuum birefringence (see references). At the moment they need to be settled with some theoretical developments, especially the vacuum birefringence. My proposed activity could include preliminary studies of the relevant literature (very scarce indeed, from which my interest) and additional theoretical work.
4-REFERENCES:
--About Gravitobirefringence:
A B Balakin "Gravitational radiation and birefringence induced by curvature" Class. Quantum Grav. 14 (1997) 2881–2893. and references therein
--About GW induced time dilation:
private discussions with :
Kip Thorne, Alessandra Buonanno, Massimo Tinto, Eugene Cowan and , by e-mail, other colleges in Italy (Valeria Ferrari and Luca Lusanna, expert in theoretical Relativity)
Closely related to this topic is the literature on Doppler tracking.

5_TEACHING SPECTROSCOPY
In order to alleviate the financial burden , I can offer teaching service in support of my stay at LIGO. This could be either at Caltech or at Universities close to the Observatories.

The target is to continue preparing, identifying and finalizing my collaboration with LIGO while living in the US. I could teach the same classes that I teach at my University in Rome.
5_REFERENCES:
see the program below and the transparencies of my course (available at the Univ of Rome).

IN SUMMARY:
At the end of this two-month grant period, I have collected enough information and evaluated the various LIGO activities to be able to propose the following:
-As a main activity, I propose to work on the LIGO INTERFEROMETERS, both at the 40 m and the sites, collaborating also with Hiro Yamamoto for matching his simulation programs to the interferometer realities.
-I would devote some time to DATA ANALYSIS (to be further studied as described in paragraph 1- above), and, if time will be available, to technical and theoretical investigation related to alternative ways of detecting GWs (as described in paragraph 3- above)
-Finally, in order to justify my living expenses here in the US , I can offer teaching classes in SPECTROSCOPY with the following program:

-SPECTROSCOPY CLASSES-
(a program of classes taken by prof A.Cacciani for students of the 4th year in Physics at the University of Rome1))

1) BASIC TENSORIAL CALCULUS

2) MAXWELL EQUATIONS AND ELECTROMAGNETIC WAVES:

   Poynting. Maxwell tensor. Scalar and Vector potential. Gauge invariance. Lorentz gauge. Plane wave and its energy and associated momentum. Radiation pressure.

3) STELLAR INTERIOR AND ITS EQUILIBRIUM

   Idrostatic equilibrium and politropics. Convective and radiative energy transfer. Schwarzschild criterium. Sistem of equations for the stellar equilibrium. Application to the Sun. H-R diagram. Solar Oscillations. Neutrinos from the Sun.

4) ANALYSIS OF THE ELECTROMAGNETIC RADIATION

   Polarization of light : Stokes parameters and Jones Calculus. Spectral analysis of various wave-forms. Fourier Transforms. Theory of gratings and interferometers. Fourier Spectroscopy and Michelson Inerferometers

5) INTERACTION MATTER/RADIATION (quantum theory)

Dirac equation for a free particle and for a particle in electromagnetic fields. Pauli theory as zero order approximation of the Dirac theory. First order approximation of the Dirac theory and the Spin of the electrons. Quantization of the Electromagnetic Field. Operators that modify its quantum state. Hamilton form of the field equations. Interaction Matter/Radiation as evolution of the total quantum state Radiation+particle. Approximate solutions (time dependent perturbations). Statistical equilibrium for the total quantum state. Computation of the Matrix Elements. Statistical equilibrium for the atomic quantum state. Radiation transfer in a medium. Formal solution for the Transfer Equation. Formation of spectral lines in the case of Local Thermodinamic Equilibrium (LTE)