Virgo Progress Report
For the STAC and EGO Council

Including a Special Request for Fellowships in Data Analysis

VIR-016A-07
June 13 2007

Abstract

This report describes the Virgo activities and progress for the December 2006 to June 2007 period. It starts by a status overview and collaboration news, and is followed by five sections describing in more details the detector, commissioning, data analysis, Advanced Virgo and outreach activities. These sections haven been prepared by the corresponding coordinators with inputs from various persons.

A special request for data analysis Fellowships is also included at the end of this document.

3

Summary

3

1 Overview

1.1 Recent activities:

The commissioning work and the preparation of the first Virgo science Run (VSR1) remained our main priorities over the last months. Significant progresses have been made and we were able to start VSR1 on May 18th. The figure 1 shows the Virgo sensitivity at the beginning of VSR1 compared to the four running LSC detectors. For the low frequency part of the spectrum, Virgo is the best detector. For the mid range frequency the LIGO detectors are still better and above a few hundred Hz, the detectors have equivalent sensitivity (except GEO600).

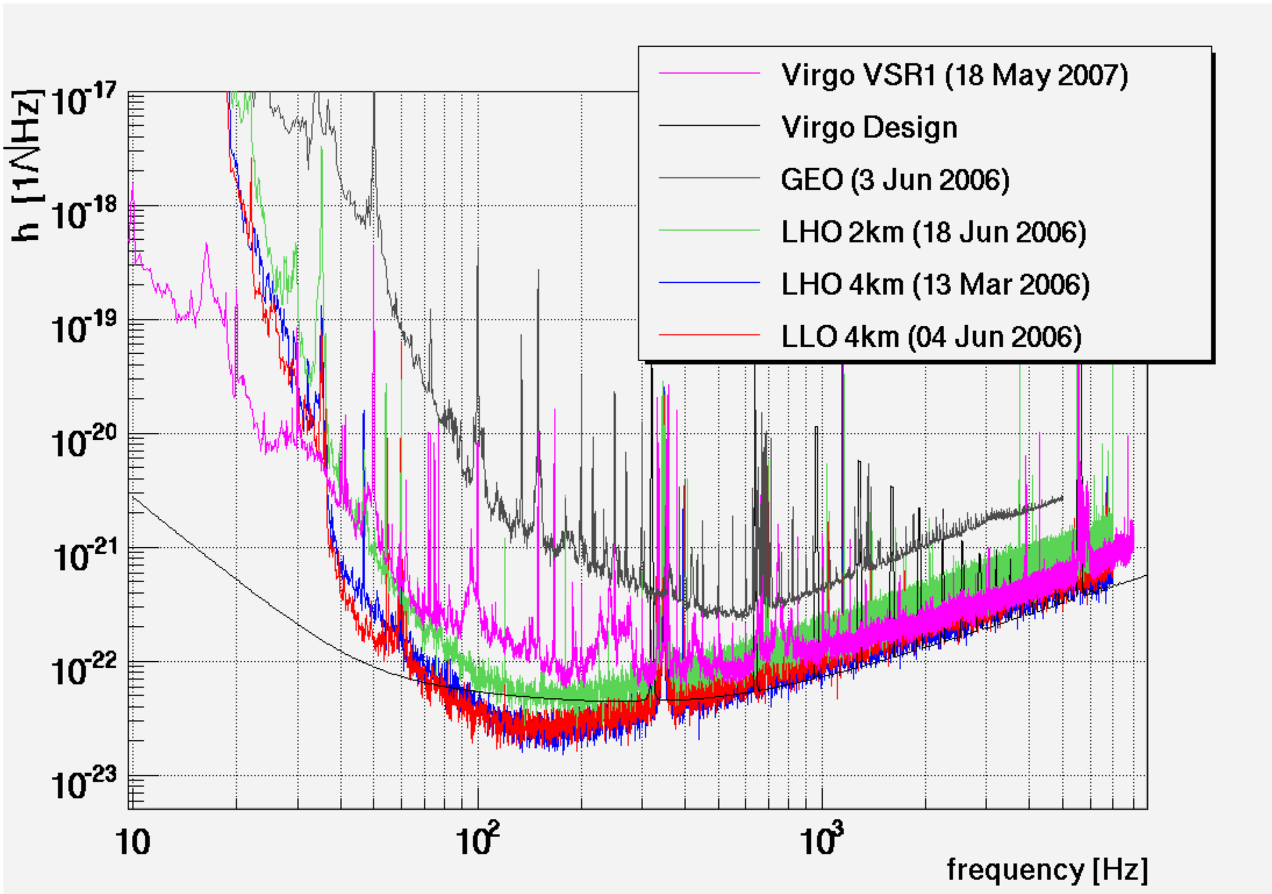


Figure 1 : Virgo sensitivity at the beginning of VSR1 compared to the LSC detector sensitivities running at the same time

This achievement was for us the opportunity to organize of press conference which was attend by journalists from the main French and Italian newspapers and scientific magazines. For this event we had the participation of the top members of the funding agencies, including an NSF representative and several EGO council members.

The organization of the run worked well with a positive answer of all the VIRGO groups to provide the scientists on shift in addition to the operators (from EGO) for the four months of the run which are currently scheduled. The science mode duty cycle observed at the time of writing this report (i.e. three weeks after the start of the run), is 87% (see figure 2) with lock segment lasting up to 58 hours.

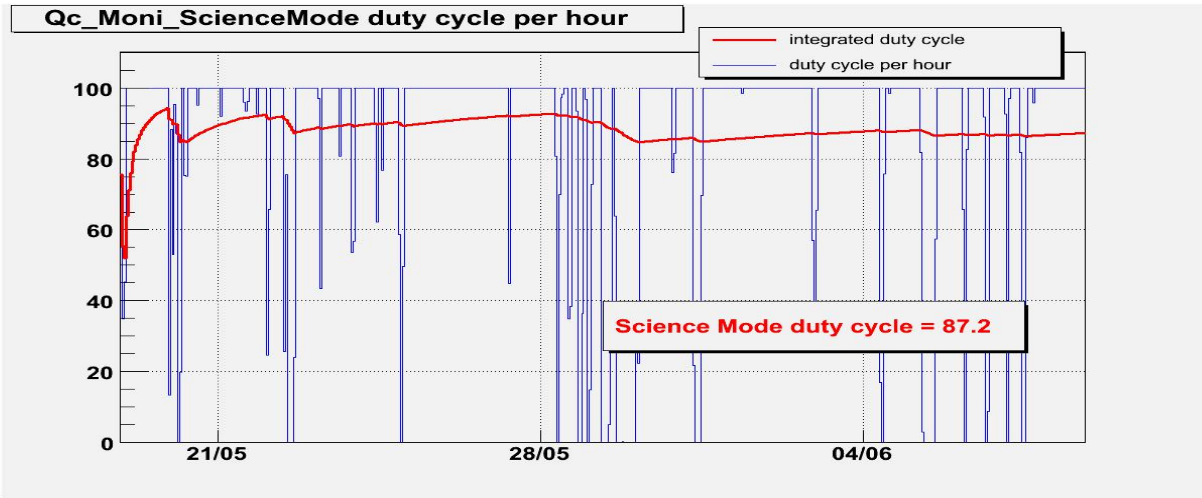


Figure 2 Science mode duty cycle for the first 3 weeks of the run.

The data analysis people worked in parallel on the analysis of the data taken during the Week-end Science Runs (WSR) and the setting up of the joint LSC-Virgo analysis. The data analysis section describes the achieved work, but it becomes clear now that the data analysis activity is understaffed. Since we are entering a new phase, we need to reinforce this activity and this is why the collaboration is submitting a special request for fellowship (see the attached document).

As a consequence of the priority put on the commissioning and run preparation, the Advanced Virgo activity had a slow start. However, all the organization is in place. The working groups are studying different options. They have presented some possible paths and are working with the aim to provide a preliminary design and cost plan around the end of 2007.

1.2 From VSR1 to Virgo+

While Virgo is currently taking data, the post VSR1 activity is in preparation. ***Our main target remains Virgo+ with the goal to be back online at the same time of enhanced LIGO (i.e. mid-2009) with a sensitivity as good as the one of enhanced LIGO.***

At the end of VSR1 a commissioning period a several months will take place to improve the sensitivity in the low and mid frequency range. Then, the different parts of the Virgo+ upgrade will be installed in several bunches in 2008. This will be followed by a global commissioning in order to start the second Virgo Science Run (VSR2) around mid 2009.

During these commissioning periods, we will take each opportunity given by the Virgo+ installation planning to collect data in a so called “astrowatch” mode. These are data that are recorded at when the interferometer is in condition to run and could be analyzed if a very loud event like a supernova is observed in our galaxy. However, our priority will remain to complete the Virgo+ installation in due time which means that we do not expect that the length of these short data taking be driven by the data analysis needs.

We believe that the best strategy to increase our chance to observe an event is to move as soon as possible to Virgo+. ***This strategic choice that we are submitting to the EGO Council*** is based on the fact that LIGO will have one year of data already recorded. Collecting several weeks or months of data in 2008 with a detector having above 50Hz a similar sensitivity as the current LIGO detector will not lead to interesting scientific publication, beside the special

3

case of a very loud event but very rare event covered by the astrowatch mode. This is why we want to keep the priority for the detector improvement and commissioning during this period.

The baseline of Virgo+, and may be more important, the sequence of installation is still under discussion. A first review of the Virgo+ proposed upgrades took place last April. A second review is foreseen for next fall to asses the readiness of all our options and adjust our planning. The detector part of this document will summarize the current status. Our goal is, however, to provide a sensitivity (inspiral horizon) at least as good as enhanced LIGO, which means better than the Virgo design by a factor 2. The installation of all the foreseen Virgo+ upgrades will eventually lead to larger sensitivity improvement, especially at low frequency, but is also very challenging. It should be expected that part of this additional gain will come after the start of VSR2, taking the advantage of experience and "commissioning breaks" during VSR2.

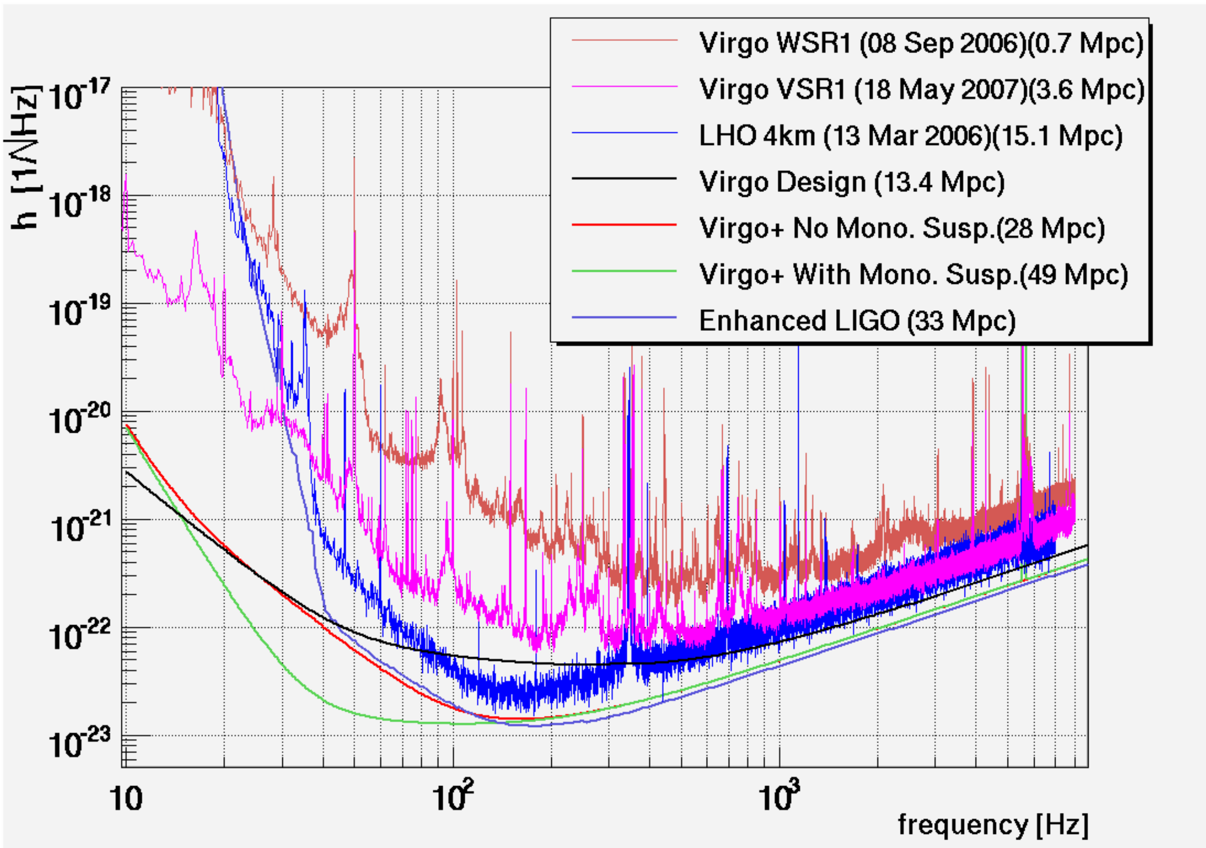


Figure 3 Progress of the Virgo sensitivity curves over the last 9 months compared to the LIGO sensitivity, the Virgo design and two versions of the Virgo + sensitivity. It should be noticed that the Virgo+ sensitivities are now computed with a finesses of 150 (instead of 50) which improve the central band and that some technical noise based on an evaluation of the actuator noise have been added. It should be underlined that these technical noises which are limiting the sensitivity at very low frequency are by definition not absolute noises. Their level may vary depending on many parameters like the exact configuration of the control system and therefore, their exact prediction is difficult.

To illustrate the possibilities and the challenges of the move to Virgo+, the Figure 3 shows the progresses made on the Virgo commissioning over the last 9 months compared to the Virgo design noise and Virgo+ sensitivity with and without the monolithic suspension. Check the commissioning section for the description of the difference between the current and design sensitivity and the plan to improve the sensitivity. The LIGO sensitivity, which is also plotted,

3

is better than the Virgo design in the central part because LIGO used cavity with higher finesse. The replacement of the mirrors and the increase of the finesse is part of the Virgo+ baseline. The high frequency part will be improved by an increase of the laser power. A Thermal Compensation System will be installed to mitigate the mirror thermal deformations. The low frequency is the part where the gap is the largest. It is however recognized by the community that Virgo has a unique opportunity to explore the low frequency range which is very promising for the scientific point of view. Making progress there is very important for the advanced version of the detectors. Keeping this aggressive goal is possible but may require additional resources (people, additional test facilities or spares mirrors for instance) to provide fallback solutions.

1.3 Collaboration organization- New groups

The collaboration keeps growing. The INFN Genova group showed interest in Virgo early this year. This group has expertise in surface and material science. They proposed to study and develop methods to assess the chemical composition of the pollution on the mirrors (on-site, whenever possible), to participate to the R&D activities on Advanced Virgo, especially in the third Working Group, WG3 "Suspensions and thermal noise issues" and to contribute to the usual life of the collaboration. After discussion with the collaboration, their formal application for membership has been accepted during the collaboration meeting of May.

1.4 External collaboration

The highlight of the last period is the collaboration with LIGO. First the MOU between LIGO and Virgo has been signed after the last adjustments. This marks the start of a transition period with a deep reorganization of our work habits, especially for the data analysis activities. To implement the term of the agreement foreseen by the MOU we had to:

- Appoint Virgo co-chairs for the joint data analysis working group.
- Appoint Virgo co-chairs for the associated review committee.
- These two sets of people formed the joint LSC-Virgo Data Analysis Council (DAC) which oversight the data analysis activity.
- Appoint the members of the joint Run Planning Committee (RPC).
- Define the charges of the DAC and RPC.
- Start joint meetings of these committees. The first item to discuss was to define when starting the effective data sharing. After several discussions, and thanks to the good commissioning progress, a joint meeting of the RPC and DAC during the first joint LSC-Virgo meeting in March proposed to start the full data sharing at the start of VSR1. This was defended in from of the LSC Council who endorses this proposition with a large majority (46 to 6). Then the run schedule, especially after VSR1/S5 was discussed.
- Organized joint LSC Virgo collaborations meetings. The second one toke place in May at Cascina, right after the start of VSR1. 137 participants attend this meeting, including 62 LSC members.
- Start joint teleconferences of the various data analysis groups.
- Implement the tools for data exchanges.

Today, both collaborations are working closely. Most of the data analysis working groups have weekly teleconference. The data analysis coordinator and the co-chairs of the physics groups have even more regular contact by phone with their LIGO counterpart. The DAC and RPC are meeting on a by-weekly base.

3

The joint LSC-Virgo effort which was original focused on data analysis is now enlarging its scope. The exchanges on the technical issues are growing and are part of our joint meetings.

In addition to the strong involvement with LIGO, the collaboration keeps its participation in the ILIAS program. A very interesting outcome of this work was the preparation and submission of a design study for a third generation GW detector (E.T.) in the framework of FP7 together with all the European groups working on GW.

1.5 Data analysis effort

The close contact with LIGO underlines the weakness of the Virgo data analysis working groups which are understaffed. After the big effort made on the commissioning activity, the start of VSR1 and the prospect of more data with Virgo+, it is now time to do the same for the other fields and especially the data analysis. This is why ***the collaboration is submitting a special request for fellowship positions to reinforce the data analysis working groups*** (see the attached document).

3

2 Commissioning

2.1 Introduction

At the time of the last report the full interferometer could be controlled and the stability and the sensitivity were good enough to make short scientific data taking (WSRs). However the controls needed to be improved in order to reduce noise reintroduction to the dark fringe, the alignment strategy was not yet complete and the immunity against weather conditions had to be improved. The lock acquisition was also not very robust.
Concerning the longitudinal control, the first improvement was the reduction of the noise of the control of the PR mirror which had an impact in the intermediate frequency range. Then, to further reduce the longitudinal control noises better on-line subtraction techniques have been developed. A better laser frequency stabilisation is also now performed thanks to improved electronics.
Developments have also been carried out on the global alignment in order to increase the loop gains for a better stability, to reduce the control noise and find a better alignment strategy. The centring of the mirrors has been improved and is now at the level of the millimetre.
The mirror suspension control has also been well improved. A better decoupling of the interferometer with respect to the ground could be performed. Concerning the immunity with respect to the weather conditions several strategies have been developed in order to be able to handle different types of seismic activity (micro-seism, wind). A better decoupling of the different degrees of freedom has also been performed. All these improvements result in a better stability of the interferometer and an improved stationarity of the data but also in an increased duty cycle. The interferometer duty cycle could also be increased thanks to some fixes in the software used in the controls.
The lock acquisition is still the critical step due to the thermal lensing effects discussed in the previous report: the lock acquisition turns out to be very sensitive to small changes in the ITF parameters and a fine tuning of the locking parameters is needed during the thermal transient.

In parallel to the activities related to the control of the interferometer, the impact of environmental noise (acoustic, seismic, magnetic) has been investigated. Some sources of diffused light were found on the end building optical benches and at the detection port. First the optical setup of the benches has been improved, then acoustic enclosures have been installed around these benches in order to reduce the environmental noise. The detection Brewster has also been replaced with a larger one since it did not meet the standard size requirements and this part of the interferometer was known to be very sensitive to environmental noise.
Some sources of magnetic noise have also been identified and cured: it was found that the magnetic noise creates a motion of the input mirrors through the magnets attached to them (due to a wrong polarity). Environmental noise however still affects the Virgo sensitivity and the investigations will go on.

The calibration uncertainty has been well reduced (from about 40% to 10%) thanks to more precise measurements of the actuators gain and by measuring and taking into account the frequency dependence of this gain (see Data Analysis report).

The scientific run started as foreseen on May 18th. The average NS-NS horizon is around 3.5 Mpc and the stability and the duty cycle of the interferometer are good. The observation on long periods already allowed identifying some improvements which are being implemented or

3

planned. A comparison of the VSR1 sensitivity and the sensitivity at the time of the last STAC (WSR5) is shown in Figure 4.

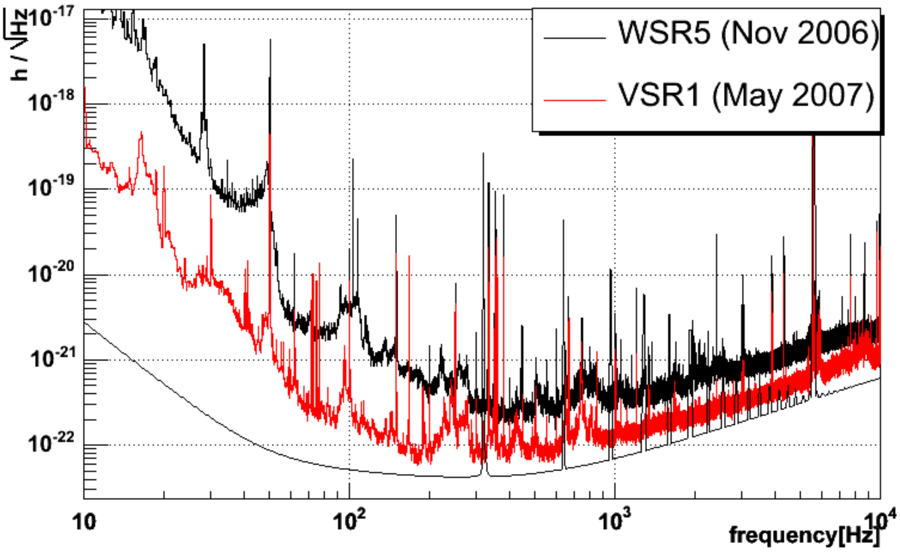


Figure 4 Comparison of the VSR1 and WSR5 sensitivities. The Virgo design is also shown

2.2 Detector operation, electronics and software

2.2.1 Detector operation

The routine operation of the interferometer as well as the trouble shooting (recovery from software crashes, earthquakes, etc) is performed by the operators. An efficient automation and a good monitoring (including alarm notification) is also a key to a good duty cycle in both commissioning and scientific operation. During commissioning, the work is, as usual, organized with 2 shifts of 8 hours per day.

- ***Training:*** training sessions and of the demonstrations are organised for new operators and carried out by several sub-system experts. A training session for the Scientist on shift during VSR1, is under preparation.
- ***Procedures*:** The procedures to operate the interferometer are regularly updated by the relevant sub-system experts and a few operators. In particular the full procedures for complete interferometer electrical shutdown and restart have been written and successfully tested during the April shutdown. A new procedure system, database and web based, with powered features of consultation and updating, has been conceived and developed.
- ***Automation:*** The automation is regularly upgraded following the evolution of the control needs. Its robustness has also been improved with better logic.
- ***Detector Monitoring System***: The Detector Monitoring centralized interface allowing to monitor the state of all Virgo subsystems by integrating the information coming from the DAQ channels and other monitoring tools has become an essential tool for the machine operations. Further enhancements (like alarms notification by sms or e-mail) are underway.
- ***Interfaces and operation display:*** For better support and troubleshoot in Control Room better GUIs for the operators are being developed. A new web page for the Detector operation has been put on line (http://wwwcascina.virgo.infn.it/commissioning/detectoroperation/index.htm), it contains also dynamic sub-pages displaying the current actions on the ITF and its status: these features are particularly useful for persons outside the control room.

3

2.2.2 *Electronic and software*

Recent activities

Main activities have been focused on improving the software used in the control of the interferometer (Gc, Suspensions) to make it compliant with the needs and more robust (increasing the duty cycle). The main change in the DAQ was the change of channel and files naming convention to make it compliant with the LSC convention. Usual maintenance and user interfaces development have also been carried on. Many activities are interlaced with the detector operation (see section 2.2.1).

Global Control

Upgrades to alignment has been put in operation based on the same scheme as the one used in locking, ie: Sensing, Filtering, Driving. This new Alignment provides switch between algorithms and the possibility to inject lines or noise after sensing (see section 2.2.2).

Suspension

Bad data (infinity, NaN) arriving to the DSP (from GC for example) were triggering the opening of the controls and exciting the suspension. A new version of the DSP code compiler has been put in operation for bad data blocking. Numerical noise was found to limit the sensitivity around 100 Hz. A low arithmetical noise filtering has therefore also been implemented in this new version.

DAQ

Naming conventions have been updated in order to be compliant with the *LIGO* data:

- Add a prefix to all the channels: “V1:”
- Align file naming convention: V-{type}-{GPS}-{duration}.gwf

This had implied the rebuild and reconfiguration of the whole DAQ chain on top of the main library Fr. Such major upgrade went rapidly and smoothly into operation.

OS Platforms and Virgo Software Releases

The migration of the Virgo software to the new OS Scientific Linux SL4 has been successfully completed. SL4 is providing the needed unique and stable platform for all Virgo workstation software during VRS1.

A Major VCS-5. Virgo Common Software Releases has been deployed at the end of March and most of the software have been frozen within it before the start of the run.

User Interfaces

Finalized User interfaces (LabView based) for the Injection, Suspension, Locking and Alignment Subsystems has been made available in Control Room.

It is also worth mentioning that a complete electrical shutdown of the interferometer has been done in April to allow electrical and computing upgrades (see Detector coordinator report) and that no big hardware problems were encountered at the restart. The ITF could be relocked within a couple of days.

Planned activities during and after the science run

Minor fixes/upgrades are under preparation for: problems of data writing on disk, the freezing of some online applications, new Labview based interfaces and upgraded Web pages.

The main planned or ongoing activities are:

3

1. A new version of the DSP server has been developed in order to cure the problem of big number (10^15) read by the DSP. It will be put into operation when needed (at the moment only one event reported in VSR1 during lock acquisition).
2. New version of the Locking Monitor web application (using msql database) which includes new features to provide more information to the user: Science Mode segments available in LSC format, hardware injection (both Bursts & Inspirals) information (LSC format), maintenance periods, and unlock reasons.
   It will be tested and put in operation during the run.
3. The laser input power tuning via motorized wave plate application is being developed in the Optical lab for deployment at the end of VSR1 (see Detector report, 1.3.4.4)
4. 8 MHz Setup: a new generator and frequency splitter is been acquired in order to phase lock the 8MHz and the 6MHz modulation frequencies and allow using a higher modulation index for the 8MHz

2.3 Interferometer control

2.3.1 Angular control

The Virgo alignment system presently controls the alignment of all 6 interferometer mirrors and the steering of the input beam; so, apart from input beam translations, which are supposed to be negligible, all alignment degrees of freedom are frozen. There are two control strategies in use: fast (bandwidth 3 Hz), and drift control loops (10 mHz). In the latter, the autoalignment error signal is just added to the error point of the local control system, which remains active and determines the noise performance at high frequencies (> 10 mHz). The end mirrors, the power recycling mirror and the beam splitter tilt motion have fast controls, the other degrees of freedom drift control.

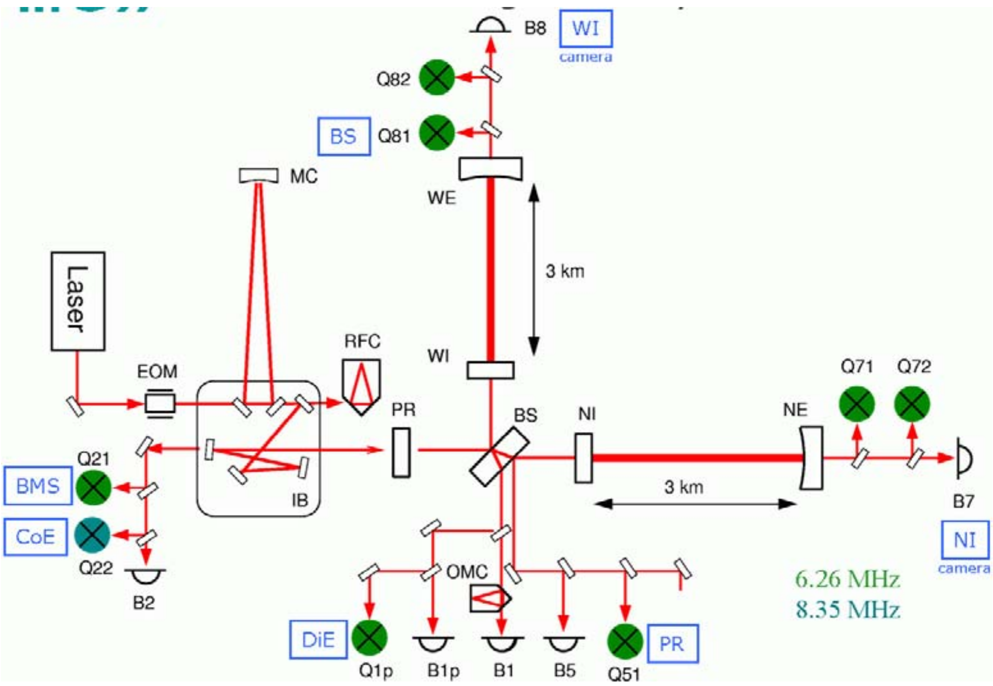


Figure 5 Virgo alignment layout. The blue rectangles show the degrees of freedom controlled with each quadrant diode (green circles). NI/WI = North/West input mirrors; BS = beam splitter; PR = Power recycling mirror; BMS = input beam steering system; CoE,DiE = Co

3

Recent activities

Global control upgrade
In order to increase the flexibility of the control strategy during the locking sequence, the alignment part of the global control system was upgraded such as to be similar to the longitudinal locking part. In particular, there is now a complete signal treatment chain, consisting of sensing matrix (constructing the alignment error signals from the quadrant diodes), filtering stack (calculating the correction signals), and driving matrix (distributing the correction signals to the mirrors). Noise and lines can be injected into the error signals in order to measure transfer functions.

Alignment controllers
Considerable effort was invested in developing the control strategy: correction filters and switch-on sequence of the various degrees of freedom. In particular, it turned out that the correct switch-on timing of the power recycling and end mirror controls were critical for keeping the interferometer stable during the critical period of the thermal transient. Moreover, the high gain / low noise correctors developed for science mode cannot always be used during the switch-on period, since large gain variations may occur. So a switching of the filtering strategy according to the status of interferometer lock acquisition has been implemented.

Common end mirror alignment control
The common end mirror alignment mode was until recently controlled by a DC (= position) signal from Q21 in the reflected beam of the interferometer. This signal had a sufficiently low noise level, but caused a dependency of the end mirror alignment from the position of the quadrant diode and from thermally caused beam deviations. Demodulated ("AC") signals are free form these effects, since they measure not an absolute beam position, but the relative misalignment between beam and interferometer. In order to obtain a demodulated signal, a second modulator was added in the input beam path, with a new modulation frequency of 8.35 MHz. On the contrary to the carrier, the sidebands of this modulation don't enter into the recycling cavity and the demodulated signal senses the common end mirror motions. A second quadrant diode, Q22, is now demodulated at 8.35 MHz and gives the correct misalignment signal. Unfortunately, the 8.35 MHz modulation index had to be kept quite small (0.01), in order to avoid interferences with the 6.26 MHz modulation. This problem should be solved in the mid-term future by phase locking the two RF generators. In the mean time, the (noisy) Q22 signal (low frequencies), and the Q21_DC (high frequencies) are combined into a lower noise error signal.

Centering of the beam on the mirrors
Since centering of the beams on the arm cavity mirrors is crucial for not converting alignment noise to length noise, an automated centering was developed: a sinusoidal perturbation (at < 10 Hz) is applied on both end mirrors, in tilt and pitch; sinus signals are measured in the longitudinal controls and the cavity input mirrors are steered for changing the beam pointing on the end mirrors until the perturbation is minimum. This resulted in a centering accuracy of about 1 mm.

A similar method was carried out by hand for performing a one-time centering also of the input mirrors, also with a similar accuracy.

Alignment noise budget
Figure 6 shows an alignment noise budget. As it can be seen, the noise caused by the different alignment loops has no incidence on the noise visible on the dark fringe. The closest degree of

3

freedom, common end tilt ("tx"), is still a factor of three away; an improved corrector has been developed, but it is not yet implemented.

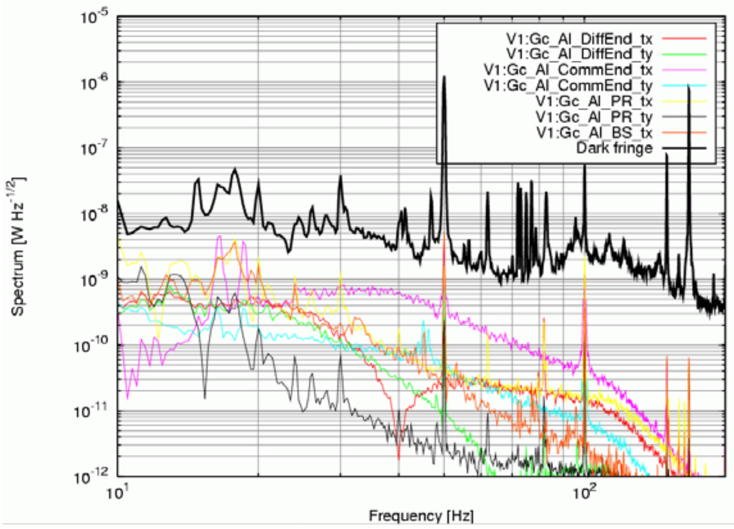


Figure 6 Alignment noise budget, obtained by injecting noise into the global control signals

.

Alignment system plans

Control scheme changes

Depending on the advancement of post-science run commissioning, some changes in the control strategy have to be envisaged. The present scheme controls the arm beam pointing by steering of the input mirrors, whereas the matching of the beam with the arm cavity axis is controlled by acting on the beam splitter and on the input beam (BMS): reversing the roles of NI-WI and PR-BMS would give a more logical scheme, making better use of the available low-noise error signals.

End bench rearrangement

There is more and more evidence for the fact that the present arrangement of the end bench quadrant diodes is not optimum; their telescopes place them somewhere in-between near and far field. Having a clean near/far field configuration would make it possible to substitute the presently used camera signals by quadrant diodes, and thus to have a faster beam pointing control.

Fast centering system

At present, the centering of the beams on the quadrant diodes is performed by shifting the quadrant diodes using translation stages. This system is noisy, and so it cannot be used during science mode; moreover, the centering fluctuations on some quadrant diodes remain considerable. It has therefore been decided to install galvo scanner centering systems, which move the beam. These systems will be based on the systems GEO has been using for years without problems; one GEO assembly was successfully tested on the North end bench in a configuration very close to the final one. One of these systems could be installed during the science run if needed.

New quadrant diodes

New quadrant diode electronics is in development at the NIKHEF laboratory. They will have several advantages with respect to the present ones: reduced preamplifier noise, reduced DC

3

current drifts, increased maximum light power and therefore reduced shot noise, better output filtering for reduced dephasing and more filtering margins (see detector coordinator report).

2.3.2 Longitudinal control

Most of the lock acquisition problems have been solved in the previous period and during the past six months the activity has mainly been focused in the reduction of the noises induced by the Length Sensing and Control system through the improvements of the Locking. Concerning the lock acquisition, it should be underlined that the robustness still remains an issue. This is mainly due to the thermal transient. It has in particular been noticed that small changes (few percents) in the input laser power can dramatically change the sidebands behaviour during the thermal transient, leading to systematic unlocks. It was therefore needed to finely adjust the locking parameters (demodulation phases, offsets, gains, engagement of the alignment loops) used during the lock acquisition and the thermal transient in order to increase the robustness.

Improvement of locking loops

During WSR1 (see previous STAC report), the sensitivity was limited by longitudinal noise below 200 Hz. It was due to the coupling between small lengths (Michelson and Power Recycling cavity length (PRCL)) and the dark fringe. Two ways have been investigated to reduce the noise. The first one is to use a more sensitive signal for PRCL (so-called switch from B2_3f to B2). The second one is to use a non-diagonal matrix and frequency dependent between lengths and mirror positions (α and β techniques).

Use of B2

The use of B2 signal which is less noisy than the B2_3f signal (B2 signal demodulated at 3 times the modulation frequency) has not been straightforward. Unforeseen offsets in B2 prevent a good stability of the interferometer on long time scales. These offsets are probably due to the use of the Anderson frequency as modulation frequency, which makes the longitudinal signals sensitive to misalignments and beam mismatches. The solution is to use a mix of B2_3f and B2: B2_3f is used as reference at low frequency (below 5 Hz) and B2 at high frequency (above 5 Hz). Figure 7 illustrates the results obtained with this mixed error signal (B2_mix).

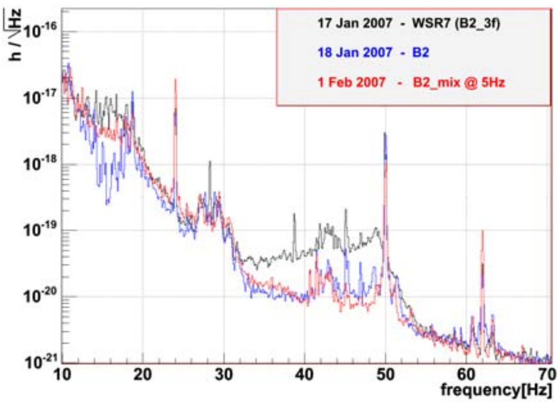


Figure 7 Improvements due to the use of B2_mix. The plot presents the sensitivity obtained using three different signals (B2_3f, B2 and B2_mix) for the PRCL control

3

The use of B2_mix allows to reduce the control noise in the detection range where B2 signal dominates and to keep good long term stability thanks to B2_3f signal at low frequency.

Online subtraction : $\alpha(f)$ and β

The second way to reduce the impact of the control loops on the sensitivity curve is to use a more complex matrix between lengths and mirror positions: it mainly consists in applying corrections to the end mirrors in a way to compensate for the noise induced by the control of PR and BS. To this purpose, two parameters α and β are introduced in the driving matrix (see Table 1).

	DARM	MICH	PRCL
PR	0	-2	-1
BS	0	$\sqrt{2}$	0
NE	.5	α	β
WE	-.5	$-\alpha$	$-\beta$

Table 1: *Driving matrix between reconstructed lengths (DARM, MICH and PRCL) and the mirror positions.*

It appears that the value of α is not constant over the whole spectrum and thus it is mandatory to implement a frequency dependant α. The shape of $\alpha(f)$ seems very robust and no significant difference has been noticed on week time scale. The only tunable parameter is the overall gain of the filter. Using Alp functionalities, this gain is continually estimated using injected lines and is updated in the Global Control every second. The same tuning is performed for the β coefficient. This online subtraction allows reducing the BS control noise by a factor 50. Figure 8 presents the results of all these improvements. The control noise is compliant with the Virgo design above 50 Hz while it is the limiting factor below.

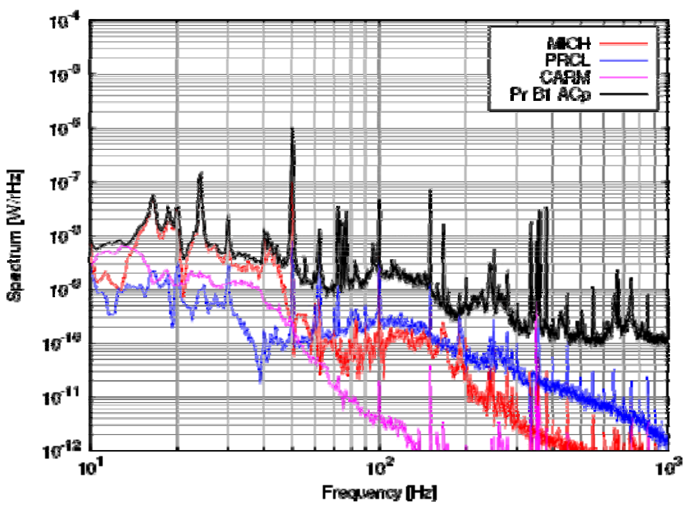


Figure 8 Contribution of the control loops on the dark fringe noise.

Second Stage of Frequency Stabilization

In order to reduce the impact of frequency noise at high frequency and to have cleaner electronics, a new electronic board has been developed for the Second Stage of Frequency Stabilization (SSFS). The UGF of the control loops has been increased from 20 kHz to 30 kHz giving a better reduction factor and a better gain margin. Figure 9 presents the

3

improvements obtained with the new board. Several structures between 1 kHz and 10 kHz disappeared and except for the peak at 5.8 kHz the spectrum is cleaner.

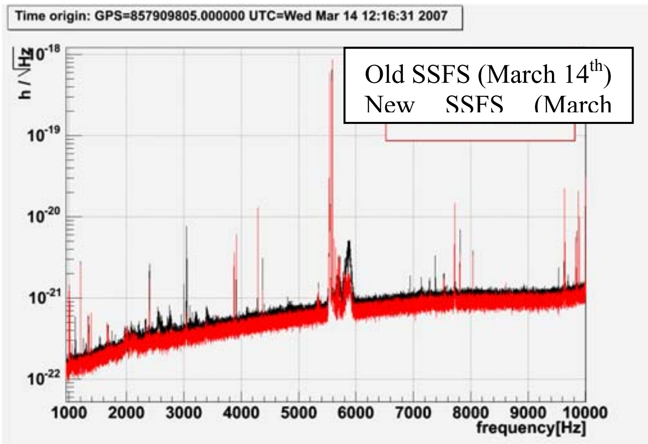


Figure 9 Dark fringe spectra at high frequency. The plot shows the improvements due to the implementation of the new SSFS board

Possible improvements

A second modulation frequency has been put in operation for Alignment purposes (see section 1.3.1). It appears that a too high modulation index leads to troubles in the control signals due to interference between sidebands induced by the 6MHz and by the 8MHz modulations. In the future, when the 6MHz and 8MHz signals will be phase locked it should be possible to use a higher modulation index. The B2 signal demodulated at 8MHz could then be used for the longitudinal control. This might help to improve the Locking loops with a slightly modified control scheme which is under study.

2.3.3 Mirror suspension control

The Mirror Suspension Control ensures a suitable control performance of the overall Virgo suspension system and is strictly connected to the *longitudinal control (locking)*, the *angular automatic control.*

Suspension Top-stages

Micro-seismic activity in the 0.2- 0.6 Hz range, usually peaked at 0.3 Hz, affects the mirror motion and consequently ITF sentivity via non-stationarities. This noise is introduced by the position sensors (LVDT) driving suspension top-stages. Lower frequency disturbance, below 70 mHz are due to local disturbance, mainly to the wind, causing tilt and are re-injected by the accelerometers. The re-introduction of these seismic noises has been reduced by developing the following strategies for the top-stage control:

- **Error-signal blending:** The best way of combining the position (Lvdt) and acceleration error signals depends on the type of seismic activity. Therefore several pre-filtering strategies have been developed. Among these, only most flexible choices are in-line for VSR1 (40 to 70 mHz crossover).
- **Global Inverted Pendulum Control (GIPC)**: In this case the local position sensing (Lvdt) is replaced by the mirror position error signal provided by the ITF photodiodes. This can be done on the four ITF degrees of freedom. By merging such a strategy with a suitable sensor blending, it also helps to strongly reject local tilt-disturbance (e.g. wind). GIPC

3

implemenation for VSR1 is enabled only for terminal suspensions (NE,WE), since they are more subject to such disturbances.

- **Vertical damping**. A vertical damping has been developed and implemented on the long suspensions. The net improvement in the dark fringe stability was evident as it was running in all long suspensions. As the need for the short suspensions level was clear, it was implemented also for the suspended detection bench. For technical reasons it was not possible to implement it for the input bench and the mode cleaner.

The gain obtained from these improvements is illustrated in.Figure 10

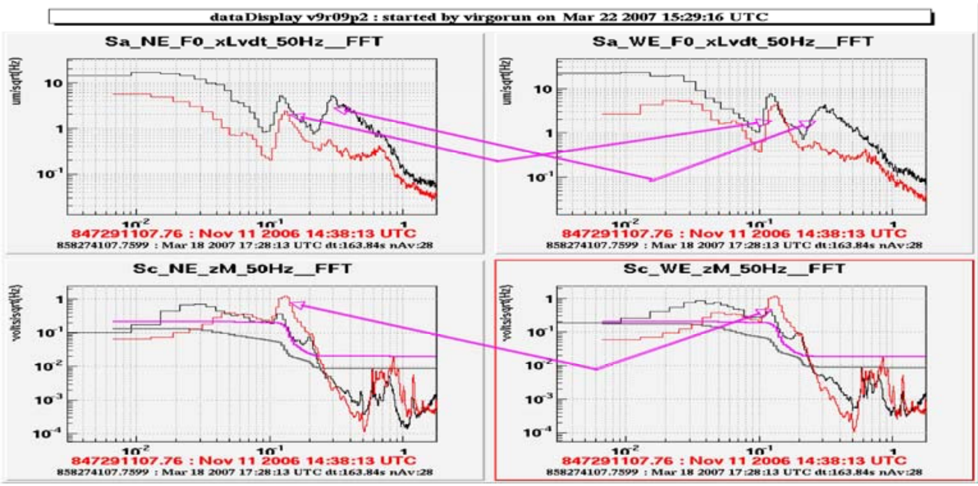


Figure 10 In spite of the larger microseism at the top-stage and a critical peak at 130 mHz (top) the correction on the marionette (bottom) is now smaller: black is now while red is before the top-stage control improvements

Suspension Bottom-stages

The improvement of the control of the bottom stage of the suspension (local control) has been the second key feature of the suspension control improvements. In addition to the optimisation of the local control filters for improved stability and low noise reinjection the following improvements have been carried on:

- **Four-marionette reallocation**. The reallocation of the low frequency locking force to the marionette was performed only on the end towers. It is now shared with the input towers: this allows a decrease of the force applied on the end mirror marionettes and a reduction of the impact of wind disturbance on the ITF alignment. However the need of this feature, in-line for VSR1, is significantly reduced after the compensation of the non-linear yaw recoil (see below).
- **Compensation of non-linear yaw recoil**: The large locking correction applied, under windy conditions, to the Marionette at the terminal mirrors (NE,WE) creates an angular motion of the Super Attenuator and Payload with a non linear coupling. This coupling has recently been measured and compensated, bringing a large improvement in the general stability illustrated onFigure 11.
- **Mirror’s driver noise further reduction**. The impact of the DAC noise had already been reduced by a factor 10 using emphasis and de-emphasis filters. After the improvements of the sensitivity in the 50-100 Hz range, the actuator noise was again a limiting noise source. Hence, another emphasis/de-emphasis filter (20-100 Hz) was implemented at the output of reaction mass actuators, to reduce both DAC and Coil Driver noise contributions without spoiling the dynamics of the actuators. This solution was implemented successfully on the Beam Splitter before VSR1 and remains to be done on the arm mirrors.

3

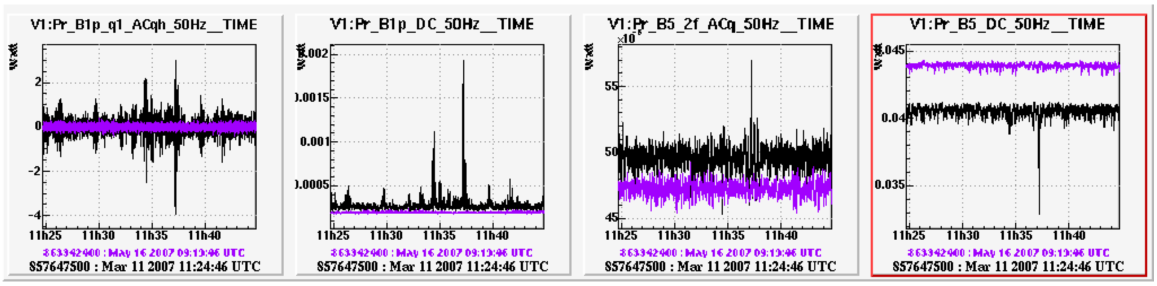


Figure 11 stability improvement in global ITF signals achieved using quadratic compensation during periods under similar low frequency disturbance: alignment error signal, dark fringe power, sideband power and recycled power.

Overall impact of MSC on duty cycle and sensitivity

In Figure 12 the empirical correlation between optimal inspiral NS-NS detection horizon, µseism and wind is reported. The empirical relation can be reconstructed as:

$$H = H_o(1 - \alpha \cdot \mu Seism^{rms(0.2-1Hz)} - \beta \cdot wind^{rms(0.03-0.1Hz)}) \ \text{Mpc}$$

From the fitted parameters (see Table below) the impact of the wind is hardly seen and the impact of µseism is reduced by a factor 5. It should be mentioned that during VSR1 the interferometer remained locked under unusual bad weather conditions.

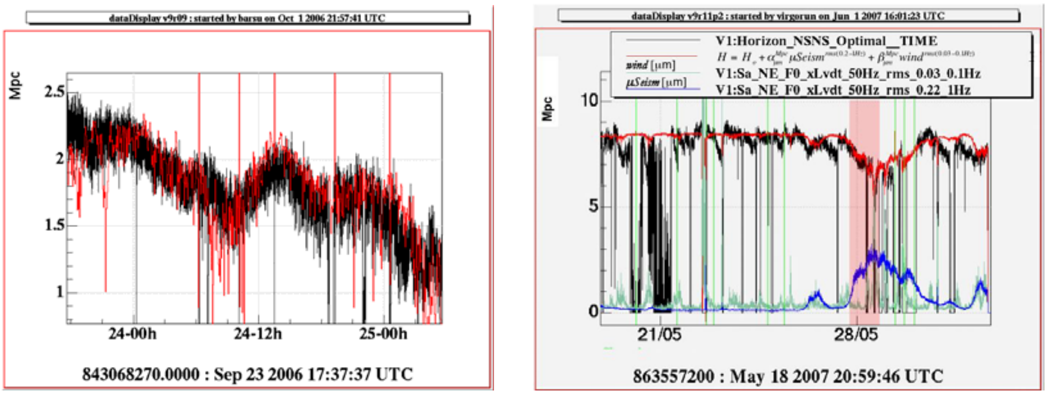


Figure 12 Left: the empirical relation reported in the last report. Right: VSR1 data display a remarkably smaller coupling between horizon and environmental disturbance.

	$H_o[Mpc]$	$\alpha[Mpc/\mu m]$	$\beta[Mpc/\mu m]$
Oct 06	2.7	0.37	0.37
May 07	8.5	0.07	0.035

<u>Possible improvements during and after SR1.</u>

The continuous operation of the interferometer will help in understanding which improvements are the most needed for a better operation. There are several possibilities:

Stability

- The GIPC behaviour under coherent ground excitation (earthquakes) should be improved. A possible solution, to be implemented after VSR1, is to use differential acceleration signals (i.e: difference between the input and end tower accelerometer signals). During VSR1 suitable alarms to disable GIPC, by checking the coherent response of IP LVDT local sensors or by means of Earthquake worldwide servers could be enough to prevent some unlocks.

- The MC and IB suspension control should be revised. In the case of MC suspension this activity will imply hardware interventions while in the case of IB it will be crucial to perform an adequate study to merge and optimize top-stage and last-stage control strategies.

Control Noise

As underlined above the impact of the actuator noise of the arm mirrors will be reduced by implementing emphasis/de-emphasis filters. However, this noise will not be compliant with the Virgo design requirements below 50 Hz, This noise could be further reduced by using a 2^{nd} order emphasis/de-emphasis filter. This new feature will be implemented in the new coil drivers (see Detector coordinator report).

2.4 Optical characterisation: thermal effects

During last months the optical characterisation activities were mainly devoted to study the behavior of the carrier and the sidebands in the recycling cavity, mostly in connection with thermal effects. Simulations have been performed using two independent codes: Finesse and DarkF. These simulations show that the sidebands are affected by thermal effects: the expected recycling gain of the sidebands is G_S=30 for the cold interferometer while in the hot case expectations vary following estimation of various optical parameters, like mirror defects and actual beam position on the mirror. Measurements show the expected cold value of G_S =30 and a hot value of G_S =11.3.

In order to provide a better understanding of the fields inside the recycling cavity and to shrink the range of parameter for simulations a phase camera has been installed on B5 (reflected by the second face of the Beam Splitter). The present camera does not distinguish among the two sidebands: B5 beam is scanned on a pin-hole and demodulated in phase at the modulation frequency. A sideband-distinguishing phase camera is presently under development (see Detector coordinator report). The measured signal for the phase camera is given inFigure 13, in the hot state. As expected the wavefront aberration is dominated by the defocus term.

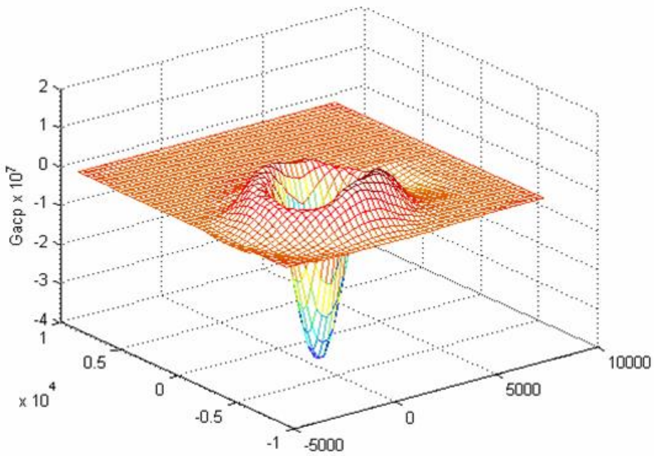


Figure 13 Phase camera signal at steady state

The same measurements have shown an unexpected high astigmatic term when the ITF is cold that get smaller (of about one order of magnitude) when the hot state is reached. Repeated measurements confirm the results. The reason of this initial aberration is still under investigation. Various hypotheses are under study, like astigmatism of input beam, or astigmatism of input mirror(s) as seen by the sidebands.

3

Thermal compensation of the mirror deformations is presently under study (see Detector coordinator report). The phase camera cannot be used as an error signal in the present configuration since it reintroduces noise at high frequency due to the scanning system. Phase camera measurements have shown that sideband wavefront, in the steady state, is highly repeatable so that also a pixellated or 'bull-eye' photodiode could be used as error signal. This system still has to be developed (see Detector coordinator report).

2.5 Environmental noises reduction

2.5.1 Diffused light

After the reduction of the PR control noise which was limiting the sensitivity between typically 50 and 150 Hz, some bumps became visible in this frequency band. Some coherence with the photodiodes located on the end benches indicated that these could be due to light diffused by the optical components located on these benches. This hypothesis was confirmed by dedicated tests: the noise disappeared when the beam was dumped before these benches and increased when the acoustic noise was increased. Deeper investigations allowed to identify some critical components and the possible improvements have then been made on these benches: more rigid mounts, larger optics and better dumping of spurious beams. Figure 14 shows the impact on the sensitivity.

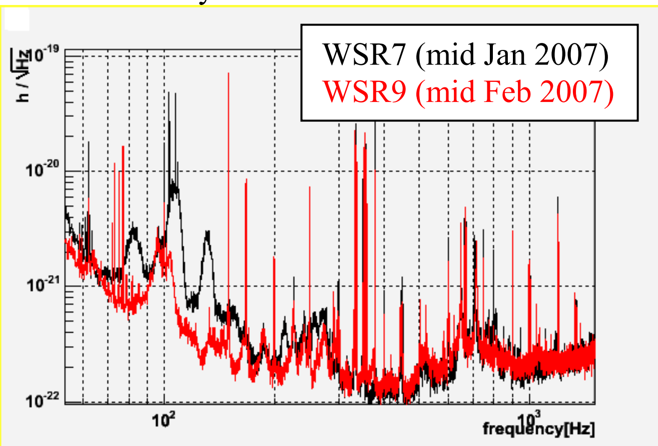


Figure 14 Improvement of the sensitivity after the reduction of diffused light by the end benches components

Acoustic tests at the end benches and at the detection port showed that diffused light was still limiting or close to limit the sensitivity in some frequency bands between 100 and 1kHz as shown on Figure 15. In order to further reduce the impact of diffused light it has been decided to install acoustic enclosures around the external benches (in the end building and at the detection port). These were produced and installed (see detector coordinator report) by the ECOSILENT company under Virgo-EGO supervision. The reduction of acoustic and seismic noise on the benches is of about a factor 3 around 100 Hz and increases with frequency up to a factor 10-20 above 1kHz.

Tapping and acoustic tests at the detection port (Brewster window and detection tower) showed that this part of the interferometer was also the source of diffused light. Since it is difficult to precisely identify the culprit several actions have been carried out:

- the spurious beams (typically from the second face reflection of the optics) have been looked for and dumped inside the detection tower;
- a larger Brewster window has been installed in order to avoid beam clipping and possible source of diffused light.

- secondary beams originating from the second face of the Beam Splitter have also been dumped before the Brewster (with black glass baffles).

Although the interferometer is less sensitive to the environmental noise arising from this area, it still is, and the coupling mechanism is not yet understood. In particular the larger Brewster did not help in reducing the noise. It was possible to reduce the noise between 100 and 200 Hz by damping the Brewster motion with some weights. This does not necessarily mean that the Brewster itself is responsible for the noise measured by the dark fringe.

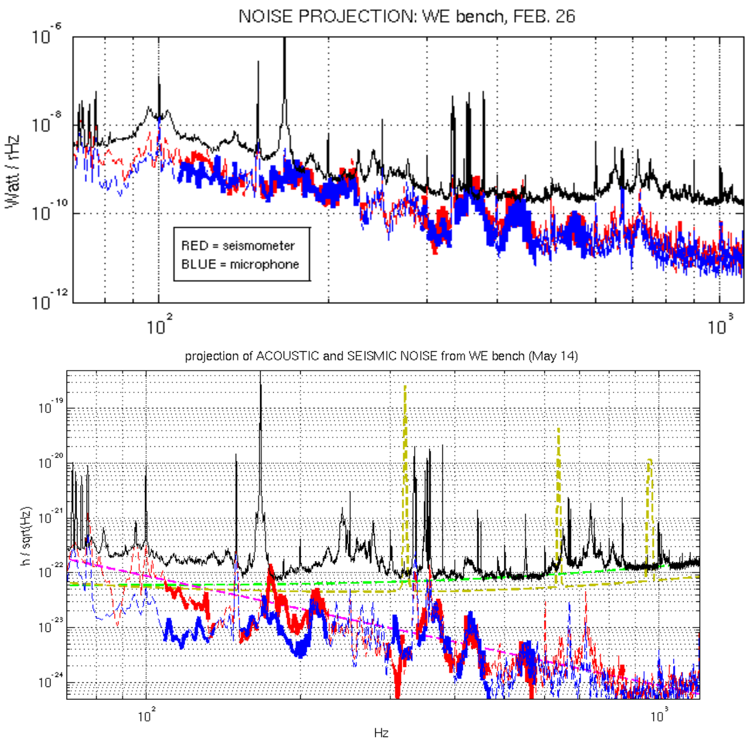


Figure 15 tentative projections of the noise induced by acoustic noise on the dark fringe before (up) and after (down) the installation of acoustic enclosures.

A couple of weeks before the start of the run some investigations have been carried out in order to understand the noise structures at 200-300 Hz and between 600 and 900 Hz: acoustic injections close to the Brewster and detection tower, tapping tests on the towers and on Brewster links. No clear conclusion could be drawn and investigations are going on.

2.5.2 Magnetic noise

After the reduction of the diffused light some noise bumps were visible around 100 Hz (as can be seen on the red curve of Figure 16). It was found that these were coherent with the signal of magnetometer located inside the central area. Some simple tests showed that this noise was not coupled to the dark fringe via the electronics (phase, amplitude noise, ground loop…) but was seen as a real motion of the mirrors. The magnetic noise should in principle not result in a mirror motion since the polarity of the magnets glued on a mirror is reversed in order to cancel the longitudinal motion. However by mistake this is not the case for the input mirrors. Sources of magnetic noise were looked for and some noisy power supplies located close to the input mirrors were found to produce the same noise as seen in the dark fringe. These were moved away from the mirror and as expected this noise was reduced.

Some magnetic noise is still likely to limit the sensitivity. For an easier investigation more sensitive magnetometers are been prepared and will be installed during the run.
The wrong polarity of the magnets will be corrected when the mirrors will be changed for Virgo+.

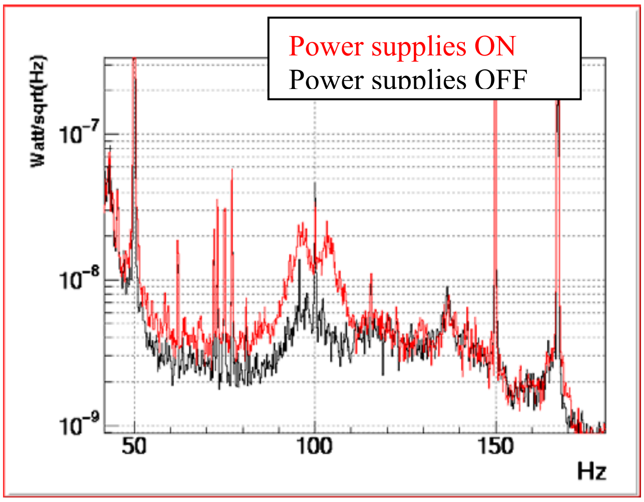


Figure 16 Effect of switching OFF some power supplies located close to the input mirrors on the dark fringe spectrum.

2.5.3 Effects of the air conditioning

It was also noticed that the air conditioning flux engendered some low frequency noise (typically up to 30Hz) on the signals acquired on the external injection bench. A better tuning of the air flow allowed reducing these perturbations. Nevertheless some improvement is still needed. The redesign of the air conditioning system could help (see Detector coordinator report).

2.6 SR1 noise budget and foreseen improvements

The Figure below shows the SR1 noise budget: the black curve is the measured sensitivity while the colour curves are the known modelled noises and the pink curve is the quadratic sum of these noises. The unmodelled noises are the environmental noises (magnetic, acoustic, seismic) which are mainly observed as the structures above the pink curve between 50Hz and 1 kHz.

Shot noise:

The shot noise is computed using the power measured on the dark fringe and taking into account the measured optical gain. It corresponds to the expected shot noise for an input power of about 7.5 W, a recycling gain of 43 and a transmission of the output mode cleaner of 80%. Above 1kHz the sensitivity is mainly shot noise limited. This agreement shows that the optical gain is well understood.

Phase noise:

The mean phase noise is well below the shot noise. However since the coupling of the phase noise is not constant (it mainly varies with alignment) it sometimes spoils the sensitivity at high frequency.

Frequency noise:

The laser frequency noise has been reduced (more gain with the improved filter) as well as its coupling (increased stability of the ITF alignment). It limits the sensitivity in regions above 5 kHz. The source of noise above 7kHz seem to be electronic noise arising from the power harmonic corrector of the UPS. This still has to be investigated.

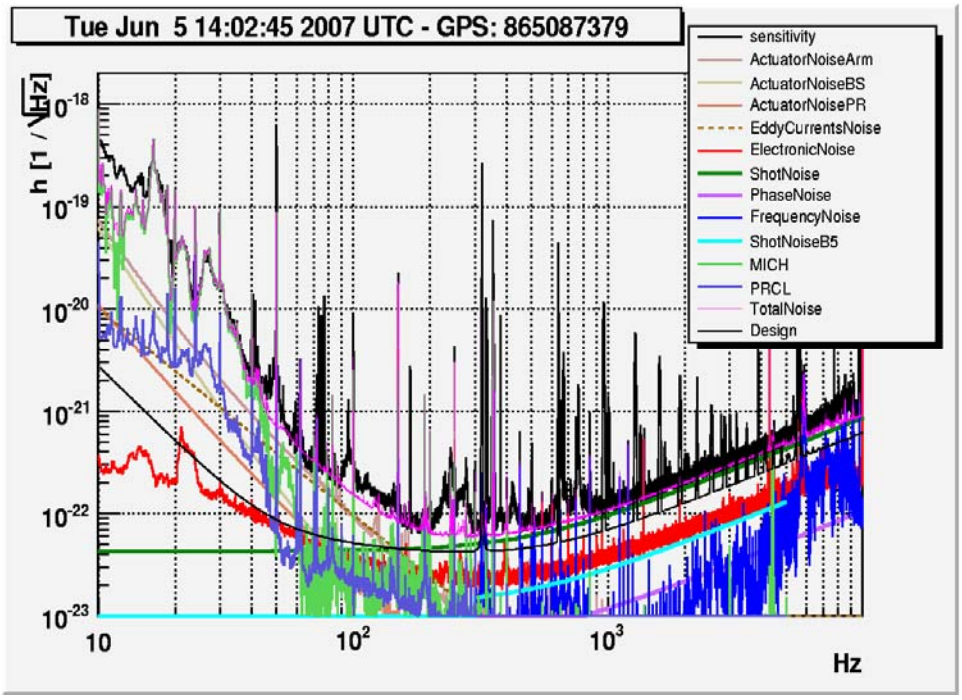


Figure 17 VSR1 noise budget

Angular control noises:

The noise introduced by angular controls does not limit the present sensitivity (see Section 2.3.1). It will nevertheless need to be decreased in order to reach the Virgo design. Since the control noise is mostly electronic noise and shot noise it will be reduced with better electronics and by sending a larger fraction of the beam to some quadrant photodiodes (mainly on B1p). Another possibility would be to improve the centring of the mirrors.

Longitudinal control noise:

The longitudinal noises are introduced by the control of the PR and BS mirrors.
The PR control noise does not limit the present sensitivity thanks to the use of an on-line subtraction. It is nevertheless about a factor 10 above the design sensitivity below 40 Hz. The origin of this noise is likely to be environmental noise inside the laser lab. It has to be better understood and possibly reduced. The coupling to the dark fringe could also be reduced since it was found that it depends on the alignment of the ITF.
The Beam Splitter control noise limits the sensitivity below 40 Hz. This noise is due to the PR control noise: PR motion is sensed by B5 photodiode and then introduced as BS control noise. Therefore any improvement in the PR control noise will lead to a direct reduction of the BS control noise. A better decoupling of PR and BS motions would also help.

The electronic noise of the mirror actuator limits the sensitivity around 100 Hz. It will be reduced by implementing an additional shaping filters. The new coil drivers and new DACs will be needed to further reduce it below 50 Hz.

3

Eddy current noise:
The noise related to the Eddy currents in the reference mass is an upper limit (this is why the total noise is above the measured sensitivity between 60 and 100 Hz). An estimation of this noise could be made when the actuator noise is reduced since it is the other dominant noise in this frequency band.

Environmental noises:
The structures around 50 and 100Hz are likely to be due to magnetic noise. This will be better understood when more sensitive magnetometers will be installed.
The structures between 100 Hz and 1kHz are likely to be due to environmental noise inside the central area. Some investigations, inside the central area, started a couple of weeks before the run and will go on.

2.7 Shot term plans

Short commissioning breaks will be done during the run on the basis of 25 hours per month. These will be focused on improving the sensitivity and, when needed, the stability (and therefore stationarity). The too risky modifications will be kept for after the run in order to try to keep a good duty cycle.

2.7.1 VSR1 commissioning plans

The planned commissioning activities during the run are:

- Environmental noises investigations (magnetic and acoustic). The first step is to get some hints, from the data, about noise sources and path to the dark fringe. Next step will imply some tests on the detector (like noise injections). Then the noise should be cured. If the operation is believed to be too risky for the ITF operation it will be performed only after the run;
- Reduction of the arm mirror actuator noise (mainly above 50 Hz): additional de-emphasis filters in the coil drivers will be implemented;
- The straightforward improvements of the controls of the injection bench and of the mode cleaner will be done to improve the immunity against bad weather conditions;
- Some alignment drifts have been cured at the beginning of the run but some still remain. This is under investigation and could partly be cured during the run (for example with the implementation of a centring system for science mode operation);
- Several strategies for the mirror suspension controls have been tested before the run but long term observation (with different type of seismic activities) are needed to understand which one is the best. The run will give the opportunity to better measure the performances of these few configurations.

2.7.2 Post-VSR1 commissioning plans

The post run commissioning activities will be focused on the following items:

- A lot of work will probably remain to be done on the environmental noise curing (100Hz to 1kHz noises). This might imply opening towers (injection, detection) for diffused light curing. If it is confirmed that the Brewster window is a limiting factor it could be temporarily removed (see Detector coordinator report).
- The improvement of the control of the short suspensions (injection bench and mode cleaner) implies some hardware reparation and more lengthy tests which will be performed only after the run;
- The end benches will be rearranged to try to obtain better alignment signals. The strategy for the alignment control will be revised if needed;

3

- The PR and BS control noises need to be reduced (low frequency sensitivity): studies have to be done to check if a better decoupling is possible. The use of the 8 MHz signal for the longitudinal control of the interferometer should also be studied: it could help to reduce the longitudinal control noises. This would imply a change of the locking strategy. The impact of environmental noise on these error signals has also to be understood and cured;
- Better stationarity will probably imply to improve the centering of the quadrant diodes during science data taking: galvanometers will be installed for this purpose;
- The angular noise will be reduced if needed: lower electronic noise (new electronic boards under development) and shot noise of the angular control error signals.

Concerning the thermal effects two actions are foreseen (see detector coordinator report):

- try to clean the input mirrors
- implement the thermal compensation system

The reduction and the control of the thermal effects will not only allow to run at higher power but it should also help to have a more robust lock acquisition. Non understood features like the offsets on some longitudinal error signals could also be related to thermal effects. If this is the case these controls could become more robust and less noisy.

3

3 Detector

3.1 Introduction

The detector activities since the last report have been concentrated in two main fields:

- Support to the commissioning activities, with the precise target to start the scientific run VSR1 in May
- Preparation of the Virgo+ upgrade

The full list of activities is documented through the “Change Request” (CRE) tool in the web page:
http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/index.html
and here we report a subset of the most important items.

3.2 Support to the commissioning activities

In the first framework are included the realization and the installation of the acoustic isolations in the detection bench and in the end benches, the realization and installation of the Brewster’s windows in the detection port. A large fraction of the upgrades included in this framework have been implemented during about two weeks of shutdown occurred between the 7th and the 18th of April. In the same time a parallel, intense and fully coordinated program of maintenance and upgrade has been implemented by the EGO infrastructures, involving the air conditioning, the UPS service and the computing facilities (this part should be described in the EGO report). The full description and planning of the shutdown activities has been kept updated at the address:
http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/April2007shutdown.html.

3.2.1 Acoustic isolation of the external detection bench

This upgrade has been driven by the evidence of cross talk between the acoustic channels and the dark fringe. The exact path followed by the acoustic noise to enter in the dark fringe channel is as usual difficult to determine completely and for this reason a complete package involving the detection lab area has been realized, displacing and isolating the external detection bench from the detection tower, isolating the racks containing the detection electronics and replacing the output port Brewster’s windows with a larger one. The installation of this acoustic isolation has been completed during the April 07 shutdown. Further information on this activity are reported in the attached information form and the performances are described in the commissioning coordinator report.

Name	Acoustic isolation of the external detection bench
Code	Virchrq0022007
Documentation	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0022007.html
Responsible	E. Tournefier

3.2.2 Acoustic isolation of the end benches

Acoustic tests in the terminal buildings show a possible coupling to dark fringe via light diffused on the external optical benches. The major path seems to be this one: the sound pressure shakes optical elements on the bench. The optical elements can diffuse spurious light beams which are phase modulated by the seismic vibration. This light can re-enter the interferometer from one arm, and being not compensated by counter noise at the other arm, produce significant noise at the output port. The design of the acoustic isolation of the end

3

benches has been driven by the experience obtained with the other isolations and the installation has been performed at the beginning of May in about four day (leaving the interferometer available for commissioning in night shifts), although a preparatory work on the infrastructures has been performed during the April shutdown. Further information on this activity are reported in the attached information form and the performances are described in the commissioning coordinator report.

Name	Acoustic isolation of the end benches
Code	Virchrq0052007
Documentation	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0052007.html
Responsible	F. Richard

3.2.3 Large aperture Brewster's windows

The original Brewster's windows connecting the injection tower and the detection tower to the interferometer have been suspected to be source of scattered light because of their reduced clear aperture (that don't respect the "gold rule" of a diameter larger than 5 times the beam waist) and because a cross-coupling between the acoustic channels and the dark fringe during some acoustic test. A long design activity has been performed by a team of persons expert in optics and vacuum and mediated with the collaboration in several detector meetings. To minimize the impact on the detector and to have the chance to start the scientific run in the defined time has been decided to implement only the detection Brewster's window and its installation is occurred during the April shutdown. Unexpected problems with this component caused two successive interventions to dump some additional beam entering in the larger aperture, through the installation of an absorbing baffle in the SR tower, and to reduce the light scattered in an aluminium baffle installed in the Brewster's window body. Further information on this activity are reported in the attached information form and the performances are described in the commissioning coordinator report.

Name	Large aperture Brewster's windows
Code	Virchrq0122006
Documentation	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0122006.html
Responsible	C. Bradaschia

3.3 Preparation of the Virgo+ upgrade

The Virgo+ plan is realized by the coherent merging of the upgrades suggested by two different needs:

- the reduction of the fundamental noises limiting the current and the nominal Virgo sensitivity
- the resolving of the technical problems that are limiting the current sensitivity and reliability of the detector

For this reason some of the technical upgrades, defined through the CRE tool and identified during the commissioning activities, have been included in the Virgo+ plan and, *vice versa*, the major Virgo+ upgrades are currently inserted in the CRE program.

3

3.3.1 Virgo+ Reviews

As already described to the STAC and to the EGO council, the evolution of the Virgo+ upgrade activities is monitored and addressed through an intense review activity: first, every Virgo week, in the context of the detector meeting, some of the activities are reviewed in front of the collaboration. Second, a program of general review appointments has been set-up. The first Virgo+ review has been held at the site the 3rd of April (2007) and the related documentation is available under the detector coordination pages (http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/) at the URL: http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/firstVirgoplusReview.html while the slides of the presentations are available at the address: http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/

The date of the second review is still to be defined, but it should occur in November 2007. Other reviews are possible in 2008, but still to be announced.
The targets of these reviews[1] are the definition of a Global scenario and planning, taking in account the progress of the detector and the international situation (LIGO & GEO), to define the interfaces between the different upgrades and the possible drawbacks on the detector and finally to select the mature upgrades, realizing the Virgo+ upgrade packages. The first review has been mainly devoted to the first two targets (obviously, still to be completed) while the November review will be addressed to the completion of the selection process.
The teams involved in the upgrades have been invited to present a planning, budget and resources document[2] where the status and evolution of the activity must be described (while the technical description is expected to be more deeply explained in the corresponding CRE document). This effort has been asked to all the responsible of upgrade activity, even if different maturity levels were expected, to force people to organize better their efforts in the common Virgo+ framework. The status reports have been referred by expert people inside Virgo and in the LSC[3]. Despite of the missing report of some of the upgrade activities and despite the almost general (but expected) lack of requirements and specifications, the first review permitted to depict a first raw planning of the Virgo+ preparation and installation. The installation plan will be frozen when the mature upgrades are definitely selected, in the second full review.
In the next paragraphs a subset of the major upgrade activities is described.

3.4 Post VSR1 upgrades

It is difficult to divide the timeline of the detector upgrades in a post-VSR1 phase and a Virgo+ phase because our aim is to distribute the upgrades in a way to minimize the needed recovery commissioning. Nevertheless, some upgrade activity could be foreseen in a shorter time window respect to the longer Virgo+ shutdown (and the installation will be agreed with the commissioning coordinator) because it is quickly progressing now, or because of its reduced size or because it is strongly needed already in the current Virgo framework.

---

[1] As described in the talk:
http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/Virgo+%201st%20Review-Introduction.ppt
[2] See the template at the address:
http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Virgo+Review1.dot
[3] We profited of the collaboration of some LIGO member, like M.Evans and R.Hadikari, and GEO members like A.Freise, B.Willke, S.Rowan and H.Lueck thanks to the ILIAS-WG3 network.

3.4.1 *Thermal compensation*

The instabilities caused by the thermal lensing in the input mirrors already limit the Virgo sensitivity. In fact, the unbalance of the sidebands due to the thermal lensing is cured in Virgo by a slow locking procedure, but, mainly, by limiting the injected power to about 8W. It is mandatory, before to install the new laser amplifier, to install a thermal compensation system (TCS), and to operate Virgo at the full power. After a period of parallel development, the TCS responsibility has been attributed in Virgo to the Roma Tor Vergata group; contacts and information exchange have been opened with LIGO, since in that detector the TCS is fully operative. In principle, a similar solution will be developed in Virgo, but in practice, the geometry of the Virgo towers and payload requires an *ad-hoc* solution. The first operative design should be presented to the collaboration in the Jun07 detector meeting. The timeline for the installation of this system is still under definition, but the request is to have a first installation in Dec07/ Jan08 and to have a Virgo+ compatible system in April/June 2008. An important aspect of the TCS is the generation of the error signal. In LIGO this is realized through a custom bull-eye photodiode. It is our intention to use a similar device and we are contacting LIGO[4] to share the production of a new bunch of that device. It must be underlined that, according to the result given by the resonant mode technique, developed in Virgo, the current absorption of the mirrors are higher than the original specification and this could be due to a pollution of the mirror surface. For this reason, in agreement with the commissioning coordinator, a cleaning intervention is under evaluation in the post-VSR1 time window; the operative characteristics of this intervention aren't still defined, but the requirements are to minimize the shutdown impact on the interferometer.

Name	TCS
Code	*Missing*
CRE document	*Missing*
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Virgo+_TCS.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-05/DetectorMeeting/Alessio%20Rocchi_Rocchi%20LSC-Virgo%20TCS.ppt
Responsible	A. Rocchi – V. Fafone

3.4.2 *Phase Camera*

The phase camera is an investigation tool missing in Virgo and that it could be useful to integrate the information about the thermal lensing behaviour of our optics, currently achieved through the scanning Fabry-Perot, the mirror resonant mode technique developed in Virgo and the so-called phase_camera_0 device (unable to distinguish between the two sidebands, see commissioning coordinator report). The project had a very hard life, first to define the responsibility and then to share the production duties. Finally, just before the April Virgo+ Review, the design and production full and exclusive responsibility has been attributed to the Pisa group and the project has been restarted. According to the new plan, the phase camera should be delivered at the end of the VSR1 and it could be installed in Virgo during the commissioning phase.

[4] Private communication with D.Tanner.

3

Name	Phase Camera
Code	virchrq0112006
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0112006.html
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/PhaseCameraVirgo+Review.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-05/DetectorMeeting/Stefano%20Bigotta_bigotta_240507_phcamerarestart.ppt
Responsible	S. Bigotta

3.4.3 New quadrant diode front end modules for the Virgo Linear Alignment

This activity has been already described in the previous STAC reports; it is driven by the need of refurbish the spare parts of the quadrant diode (QD) front end modules used in the Virgo linear alignment. At this occasion, some improvements in the performance should be obtained for overcoming presently felt limitations, while maintaining full compatibility (interchange ability) with the existing modules. The desired improvements concern lower noise, higher possible incident light power, lower DC offset (and resulting lower DC offset drifts), and changing the geometry from 'X' to '+' configuration. Thanks to the backward compatibility with the previous electronics, the replacement of the old electronics will be progressive. Despite the fact that this activity has been well defined in advance, the production of the electronic components suffers of a strong delay respect to the original plan. In the current planning, the full production of the boards will be accomplished in Jan08.

Name	New quadrant diode front end modules for the Virgo Linear Alignment
Code	Virchrq0082006
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0082006.html
Virgo+ Review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Virgo+NewFEs.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/JvdBrand_4Q_FE.ppt
Responsible	H. Heitmann

3.4.4 Fast centering system for the interferometer alignment quadrant diodes

For each quadrant diode used for ITF alignment, a fast centering system which steers the beam and keeps it centered on the diode should be installed. The present system, shifting the quadrant diode front end assembly for centering, would be de-activated; the translation stages would only be used for prepositioning or occasional readjustment. The motivation of this change are mainly due to the fact that the current translation system is too slow, and it cannot keep the beam well centered in the quadrant, and it is too noisy. Because of the last motivation the translation stage is currently left inactive during the VSR1 and this causes a progressive misalignment of the Q81 quadrant (end of the West arm) and a progressive spoiling of the Virgo sensitivity that requires a periodic realignment[5]. The technical solution has been found and tested thanks to the support of the GEO scientists in the ILIAS framework and, currently, we are purchasing the components.

[5] Out of the science mode

Name	Fast centering system for the interferometer alignment quadrant diodes
Code	Virchrq0062007
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0062007.html
Virgo+ Review	*Not requested*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-05/DetectorMeeting/Heitm_070524_FastQuadrantCentering.ppt
Responsible	H. Heitmann

3.5 Virgo+ upgrades

Hereafter are reported a series of upgrades that for their size or for their origin are labelled as Virgo+ upgrades, but, as said before, they are inserted in a continuous evolution scenario.

3.5.1 Monolithic suspensions

This upgrade is the most aggressive and risky of the Virgo+ package. The aim is to reduce the thermal noise of the suspension, that limits the nominal sensitivity curve of Virgo, through the use of a monolithic fused silica design of the mirror last stage suspension. This is a 2nd generation technology and its application in Virgo+ is a real bet in terms of readiness of the upgrade and of drawbacks on the interferometer. The design and realization activity is performed by a team of persons coming from the Perugia (H.Vocca), Roma 1 (P.Puppo), Firenze (G.Cagnoli) laboratories with the support of LMA and the EGO infrastructures. The first target is the realization of a dummy payload at the Virgo site (there is a Lab dedicated in the 1500-West building) for both static and dynamic (control) tests. Currently a first trial suspension has been successfully performed and the design of few crucial components of the suspension is under progress. The planning and the status of this activity is continuously reviewed in the detector meetings and in some dedicated meeting, but the readiness of the project will be judged at the November review, taking also in account the noise performances of Virgo at low frequency[6]. Since the motivations that push to replace the payload aren't only the reduction of the nominal thermal noise, but the mitigation of the eddy current dissipation[7], the replacement of the test masses with cleaner and higher reflectivity mirrors[8] and the implementation of a x-movement optical lever, a parallel development strategy must be studied that permits the jump from the full monolithic suspension implementation to the improvement of the current payload with a traditional design. The current design of the new reference masses fulfils this requirement. Further information is reported in the attached form.

[6] It must be underlined that the planning currently elaborated by the working team is not compatible with the Virgo+ scheduling and a deep analysis is under progress

[7] The dielectric reference mass foreseen in this project could be a valid solution

[8] The design finesse of Virgo+ will be 150 instead of the current 50

3

Name	Monolithic suspensions
Code	Virchrq0012005
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0012005.html
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Virgo+Review_Monolitiche.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/MonSuspVocca.pdf
Responsible	H.Vocca

3.5.2 New mirrors

The Virgo large mirrors are currently in a mixed configuration: Suprasil for the input mirrors and Herasil for the end mirrors. This configuration, according to the experimental measurements on the loss angle of the Herasil, spoils the thermal noise performances of Virgo. With the current power and finesse this doesn't affect the detector sensitivity, but in case of increase of the laser power the mirror thermal noise will become the limit to the Virgo sensitivity. Furthermore, the use of a monolithic fused silica suspension requires the replacement of the current mirrors with test masses having lateral clamps (ears) compatible with the fused silica fibre suspension. In addition to these "scientific" motivations there are other "technical" reasons to replace the mirrors: in fact, according to the measurement performed with the resonant mode technique developed in Virgo, the current test masses show an absorption larger than the design value[9] that limit the maximum power usable in Virgo. Furthermore the end mirrors are currently without an AR coating in the back face, causing multiple beams detected in the end benches, which are source of diffused light. We will profit of the input mirror replacement to increase the finesse from 50 to about 150; this will permit to improve the sensitivity in the central frequency region and to benefit of the mirror thermal noise reduction.

The definition of the requirements of the new test masses was originally reported in the monolithic suspension package (please refer to the corresponding CRE document), but now is managed independently by EGO (R.Flaminio) with the support of the Nice lab (A.Brillet) and the LMA lab (J.M.Mackowsky). The corresponding document is reported in the following form, while the production deliverables foreseen for December 2007 (input mirrors) and February 2008 (end mirrors).

Name	FP mirrors for Virgo+
Code	Subset of Virchrq0012005
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0012005.html
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/MirrorsFPVirgo+.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/Mirrors_for_Virgo+FP.ppt
Responsible	R.Flaminio

[9] Probably because of some surface pollution

3.5.3 *Laser Improvements*

The core activity of this upgrade is the realization and implementation of a laser amplifier[10] that pushes the laser power injected in the ISYS up to a nominal limit of 50W. This activity is mainly performed by the Nice group (F.Cleva) in collaboration with LZH/GEO; since the implementation of this amplifier in the laser table will require a strong support by EGO, already an optical engineer of the EGO team (E.Genin) is involved in this task. The laser amplifier has been delivered to Nice the 24th of February and it has been performed a first series of test that preliminarily underlines the capability to supply up to 66W (with 21W of seed) and the lack of additional noise introduction (TBC). In the current planning, supplied by the team, the installation of the amplifier is foreseen in June 2008, but the project scheduling seem to permit a "safe" compression of about one or two months.

Obviously the introduction of the laser amplifier causes a chain effect[11] on many of the ISYS components of Virgo and on the input mirror requirements. Some of these changes are described in the same CRE document of the laser amplifier (reshuffling of the laser and external injection benches, new external faraday isolator installation) and they determined a budget line named "laser integration", while some other chain effect required the design of new components with dedicated CRE (i.e. remote adjusting of the suspended Faraday Isolator, remote tuning of the injected power, pre-MC realization) and budget line.

The full documentation related to these activities is linked in the form at the end of this section, and a quick overview of the related activities is hereafter presented.

Name	Laser Improvements WP for Virgo+
Code	Virchrq0022005
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0022005.html
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Laser%20improvements%20Laser%20integration_Virgo+%20review.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/Cleva_3Apr2007_Amplifier.ppt
Responsible	F.Cleva

3.5.3.1 Reshuffling of the laser and external injection benches

The layout of these benches must be reviewed to geometrically and optically accommodate the laser amplifier and optionally the pre-MC. Bringing the "four mirrors telescope" from the LB to the EIB the current benches should be able to accommodate all the additional components. New telescopes connecting the amplifier and the pre-MC have been designed. New faraday isolators (FI) have been ordered. Thermal issues on the EOM have been considered. The preparatory deliverables are foreseen within January 2008.

3.5.3.2 Pre-MC realization

To reach Virgo+ design at high frequencies a PMC should be needed to filter the power noise at 6 MHz.; furthermore, the new amplifier could have a content of higher modes so large that a pre-filtering stage is needed[12]. In effect, the design of the pre-MC has been realized for

[10] Essentially equal to the eLIGO one
[11] Mainly of thermal nature
[12] In effect a quantitative direct evaluation of the higher modes content of the laser amplifier output is missing, but from some GEO work (see B.Willke presentation at the Amaldi 6 conference) we can expect a 10% energy content in higher modes

3

Virgo and, hence, the design has been recently modified to make it compliant with the Virgo+ requirements. The preparation deliverables are foreseen to be available in the summer 2007.

Name	Pre-MC
Code	Virchrq0022006
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0022006.html
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Virgo+Review_PMC_Cleva150307.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/Cleva_3Apr2007_PMC.ppt
Responsible	F.Cleva

3.5.3.3 Remote adjustment of the suspended FI

This upgrade consists in a system for remotely tune the isolation of the Faraday isolator mounted on the Suspended Injection Bench (SIB) after the Input Mode Cleaner (IMC). The system should allow to increase the isolation factor, which is, in vacuum and with the beam aligned, lower than the maximum available one (1,000 instead of 10,000). The system consists in separating the first polarizer from the rotator, insert between this polarizer and the rotator a remote rotated $\lambda/2$ waveplate, and turn it remotely until isolation is maximised. The implementation requires also the displacement of the mirrors sending the light reflected by the Faraday isolator to the External Injection Bench (EIB) and the mounting of a mirror to take care of the input light reflected by the Faraday isolator output Brewster polarizer. The deliverables are foreseen in February-March 2008.

Name	Remote adjustment of the suspended FI
Code	Virchrq0012007
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0012007.html
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Correction%20of%20thermal%20effects%20in%20SIB%20FI_Virgo+%20review.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/lapenna_virgo+_review_030407.ppt
Responsible	P. La Penna

3.5.3.4 Remote injected power tuning

This is a system for remotely tune the isolation interferometer (ITF) input power: the power should be changed at the level of the Laser Bench (LB), using a remotely rotated $\lambda/2$ waveplate placed before the first Faraday isolator on the LB. The power reflected by the Faraday isolator input polarizer is sent to a beam dump. The system is currently meant to allow a change by not a big amount[13] the input power (by less than 25%). The aim is to have a remote control of the ITF input power for a variety of purposes, and in particular to remotely reduce the power before locking, in order to have reduced thermal effects in the ITF, then,

[13] It has been evaluated that currently a variation of 0.1W in the injected power causes a 28% variation in the sidebands ratio. Nevertheless, the 25% seems currently dictated by restrictions in the BMS that must be better evaluated.

once the ITF is locked, remotely increase the power up to the maximum available. This activity is foreseen in a time scale probably shorter that the Virgo+ one.

Name	ITF input power remote tuning
Code	Virchrq0042007
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0042007.html
Virgo+ review	*Not required*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-05/DetectorMeeting/Daniel%20Sentenac_LaserPowerTuning_LSC_VirgoMeetMay07.ppt
Responsible	P. La Penna

3.5.3.5 New MC payload

The current end mirror of the input mode cleaner shown during the commissioning many problems. A large fraction of the injected power is lost in the ISYS and the most probable responsible is that mirror, that shows a poor substrate quality. Furthermore, this mirror is very light (360g) and some control problems have been found (radiation pressure effects, departure from the simple pendulum transfer function,…). A detailed upgrade plan has been started by the M.Punturo and the Roma 1 group and now the responsibility and the competences to realize and assemble the payload have been transferred to the NIKHEF group. The realization of the new mirror is instead managed by R.Flaminio with the help of the Nice and Lyon groups. Currently the substrate, spare of the current one, has been polished by General Optics and it has been found out of specification (R~169 m instead of 180+/-2 m) and an evaluation process has been started[14]. The replacement of the payload is foreseen to be related in time to the installation of the new amplifier.

Name	New MC payload
Code	Virchrq0032006
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0032006.html
Virgo+ review	*Missing*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-05/DetectorMeeting/Thomas%20Bauer_Cascina_21_05-07.ppt
Responsible	J. van den Brand

3.5.4 New Control and DAQ electronics

This group of activities originates from two joint R&D programs supported by EGO under the STAC supervision. The need to develop new control and DAQ electronics is due to the obsolescence of the current one and to more stringent requirements (larger bandwidth, larger computing power of the DSPs, …) defined thanks to the commissioning activity

3.5.4.1 New coil drivers

The reduction of the Virgo noise, mainly at low frequency, requires also the reduction of the actuation noise. The coil drivers currently used in Virgo have been patched to reduce the large

[14] We are afraid of the capability of General Optics to obtain substrates compliant with the curvature requirements.

3

noise due to the magnets large strength through the reduction of the force dynamic range in the low noise operational mode (keeping high strength in the locking acquisition mode) and through the introduction of de-emphasis filters. These modifications have been engineered in the new coil drivers that contains also new features suggested by the commissioning activity (i.e. reduction of the offsets, insertion of a 2^{nd} order filter). In addition, to reduce the long cable path connecting the DAC to the coil drivers, the new coil drivers will be equipped with a local DAC, digitally connected to the remote DSP. The production planning suffered some delays and it has been impossible to use these devices in the VSR1, but now the producer should deliver in time to be installed during the commissioning phase after the scientific run.

Name	New coil drivers
Code	Virchrq0052006
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0052006.html
Virgo+ review	*Missing*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2006/2006-07/DetectorMeeting/gennai_050706.ppt
Responsible	A. Gennai

3.5.4.2 New timing, control and DAQ electronics

This project is composed by a series of activities devoted to the acquisition of a new GPS receiver, to the production of a new timing distribution board, TOLM, MUX/DeMUX, new differential and fastest ADCs and the use of standard PCs for the control and DAQ. These activities have been described in many previous reports; here we report just the production status.

GPS receiver: The GPS receiver has been tested, patched and certified. The order of two new devices should be accomplished

TDBox: the role of this Timing Distribution Box is to propagate the timing signals. The design is fully tested and and after minor modification of the PCB it is now ready for the production. The number of box of the different types has been defined according the new online architecture and the production is ready to start.

MUX/DeMUX: This board is a router for the optical links between TOLM and ADC boards. Prototype available. Production and tests on September-October 2007

ADC: ADC selection done (AD7674 18bit @ 800kHz); 16 differentials channels with analog anti-alias filter at 400KHz. Digital anti-alias filters in embedded DSPs(4 channels per DSP ADPS-21262 @150MHz) Several production steps foreseen, but final production expected to end in March-April 2008.

TOLM: A prototype available and used for ADC tests, TOLM /DSP interface tested. Two versions expected to be produced: PMC and PCI64 formats. Production expected for the March 2008.

Tests of regular PCs: These tests have shown that the main Virgo control loop (photodiode readout and global control) could run up to 40 KHz on a commercial PC running a real time version of Linux. This will provide more computing resource for various control loops (global and local).

3

Name	New Timing and DAQ electronics
Code	*Missing*
CRE document	*Missing*
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Virgo+Review1_DAQ-Control-Electronics.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-05/DetectorMeeting/Alain%20Masserot_20070524_Masserot_Virgo+.ppt
Responsible	A. Masserot

3.5.4.3 New DSP

Some of the current DSP are working close to the computational and memory limit imposed by a more than 10 years old architecture. The intention to increase the sampling rate in Virgo+ and the need to use more complex filters to optimize the performance of the detector at low frequency driven the necessity to realize a new generation of DSP for Virgo. The design of the new multi-DSP boards has been completed (6 x 100 MHz ADSP211160N SHARC DSP (3.6 GigaFLOPS in single PMC Mezzanine)) and two prototype versions have been produced. The production for 50 devices has been placed, while the order for the carrier board manufacturing must be still placed. After the VSR1 will be possible to test the new DSP in an old suspension control unit and, as soon as possible, an integration test with the new TOLM and the DAQ system must be performed. An installation plan must be still defined, but a pilot installation must be performed before the complete deployment to minimize the impact on the interferometer.

Name	New DSP
Code	Virchrq0042006
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0042006.html
Virgo+ review	*Missing*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-05/DetectorMeeting/Alberto%20Gennai_gennai_ligovirgo.ppt
Responsible	A. Gennai

3.5.5 TBD upgrades

A series of upgrades are under discussion in the collaboration, but their level of maturity is still so preliminary that any real opinion, documentation or planning has been defined. In this group of activities it is possible to enumerate the following items.

3.5.5.1 Brewster's window removal

The Brewster's window between the SR tower and the detection tower has been replaced with a larger aperture one, but the improvement obtained aren't really satisfactory. A discussion is started in the collaboration about the possibility to completely remove the detection Brewster's window. This will imply consistent changes in the vacuum design, mainly in the detection tower – rest of the interferometer link, because of the more stringent cleanliness requirements of the interferometer central part respect to the detection tower outgassing specifications. Some design hypothesis have been proposed, but the level of understanding is

3

still preliminary and it will be improved with a joint effort in commissioning activities (evaluating the possibility to run shortly without any Brewster's window) and detector design activities.

3.5.5.2 Anderson Technique

The choice, made ten years ago, to use a so-called Anderson frequency for phase modulation of the input beam is re-discussed. In the Anderson technique the modulation frequency is chosen such that the first Gaussian order of one of the modulation sidebands is resonant in the arm cavities. We should start thinking about the fact that another modulation frequency might be chosen which does not need to comply with this extra constraint. No profound analysis has been made yet at this point; discussions and investigations are needed (and a more focused effort is extremely necessary). Currently, the only effective step has been to introduce in Virgo a second modulation frequency (at about 8MHz) to obtain a good quality common end alignment signal.

Name	Anderson Technique
Code	*Don't apply*
CRE document	*Don't apply*
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Anderson.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/Heitm_070403_LAVirgo+.ppt http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-05/DetectorMeeting/Julien%20Marque_Marque_240507_Thermallensing-Frequencymodulation.ppt
Responsible	H. Heitmann

3.5.5.3 DC detection

The DC readout technique, based on the DC signal provided by the dark fringe carrier, will be used for enhanced LIGO and should be considered for Virgo+. This modification is motivated by smaller shot noise limit than with the AC readout scheme currently used. This new scheme implies changes in the ITF controls but also in the hardware: a new output mode cleaner will be needed, more stringent requirements on the power stabilisation and a different scheme will imply to install the photodiodes under vacuum. These investigations are started in the advVirgo framework and the possibility to extend it to Virgo+ is under evaluation, but the level of readiness of the activity and the devoted man power is, currently, limited.

Name	DC detection
Code	*Don't apply*
CRE document	*Don't apply*
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Virgo+review_DCreadout.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-04/DetectorMeeting/Tournefier_DCreadout_3Apr2007.ppt
Responsible	E. Tournefier

3

3.5.5.4 Tiltmeters

The negative effect of the bad weather on the Virgo sensitivity and duty cycle is well evident. The main responsible seems to be the ground tilting that couples, through the longitudinal accelerometers, with the suspension point of the Virgo SA. Angular acceleration measurement devices (tiltmeters) have been many times indicated as the possible solution for this problem, but any effective solution has found in the past. A new R&D effort has been started by the Pisa and Roma Tor Vergata group, but any result has been still presented to the collaboration. The full deployment of these devices in the detector is, probably, better defined in an advanced Virgo framework, but a possible limited use can been foreseen in Virgo+[15].

Name	Tiltmeters
Code	*Don't apply*
CRE document	*Don't apply*
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/VirgoPlus1stReview/Tilt%20-meters%20Virgo+.pdf
Most recent document	*Missing*
Responsible	A. Giazotto

3.6 Infrastructure upgrades

In the Virgo+ framework some infrastructure upgrades are needed. These activities are probably reported in the EGO report and are only mentioned here because they are co-ordinated in the detector framework:

3.6.1 Clean air shower

To improve the cleanliness level during the payload preparation it is foreseen to install a clean air shower in the clean room SAS. This activity is a part of a larger scenario that includes the revisiting of the mirror handling procedure already started in the Virgo+ framework

3.6.2 Power line circuit reviewing in the central building

A study and maybe realization effort will be made to understand if and how to improve the main layout of the electrical power circuit in the central building. The idea is to understand the need to sectioning the power line in each lab in the central building

3.6.3 Air conditioning

The temperature and humidity fluctuations and the air flux turbulences in the laser lab are affecting the Virgo stability and noise. An improvement of the air conditioning performances will pass through the reduction of the thermal load in the laser lab, by separating the electronics rack in a isolated volume and, possibly, by separating the air conditioning system of the laser lab by the one of the clean rooms. An investigation, leaded by the infrastructure EGO team, is started.

3.6.4 Vacuum pumps vibration noise reduction

In some of the Virgo tower there is an evident cross-talk between the vacuum pumps vibration and the dark fringe signal. An improvement program is started leaded by the EGO vacuum group and some solutions are under investigation.

[15] The idea is to measure the tilt of the ground, close to the suspension tower, and to subtract it to the signal given by the longitudinal accelerometers.

3

4 Data analysis

4.1 Services and tools

A number of activities have been continued or started in order to address general analysis needs.

4.1.1 Data Replica

The work on data replica tools has continued, and a test code based on the GRID file transfer tool FTS has been tested. Several problems have been met in setting up a stable solution, partly related with weaknesses originating from the various servers and clients involved. Therefore it has not been possible to bring this solution to the status of a production version in time for the VSR1 run.[16]

As a consequence, in agreement with the LIGO counterpart, the current production code for data transfer, developed in EGO on top of BBFTP, has been put in operation also for transferring Virgo data towards the LSC data repository, and to receive LSC data.

During the first WSRs, we had experienced problems in transferring data over the path Cascina -> Bologna -> Lyon, particularly for reasons of lack of stability of the NFS mounts at CNAF. Therefore we had moved to a Cascina -> Lyon automatic transfer + manual transfer on Bologna.

However, in time for the VSR1 the CNAF has provided in Bologna a configuration for running the bbftp transfers continuously, with a large GPFS disk area (50TB in a single volume), which makes very convenient to run data transfer jobs there.

This allowed to go back to the original, more network efficient path Cascina->Bologna->Lyon. In detail, the data transfers are now performed as follows:

Virgo raw data: are transferred automatically from Cascina -> Bologna (GPFS), then relayed again automatically to Lyon (HPSS). Presently Virgo raw data are not copied to the LSC, since no physics group requested them.
Virgo RDS: the Virgo reduced data set (essentially h-reconstructed data plus auxiliary information, about 3Mbps, are copied automatically over the paths
Cascina -> Caltech
Cascina -> Bologna -> Lyon
Ligo RDS: the LIGO reduced data set is transferred over the paths
Caltech -> Lyon
Caltech -> Cascina -> Bologna
the latter to keep a copy also in Cascina, for the groups interested in using also the EGO computing resources over LIGO data.

---

16 The work on GRID based tools will however continue, since it is believed that in the mid term GRID can provide a solution to a wide range of Virgo needs, beyond the simple data replica, including geographic data access, integrated database management and of course distributed computing. The goal is to define the needs on the basis of use cases and to develop a comprehensive solution, to be put on line in time for Virgo+.

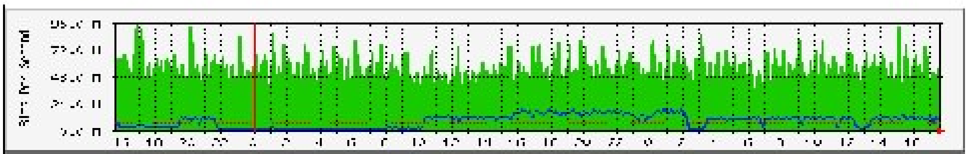
3

In the figure, some statistics of the Cascina wide area network are displayed, which show that the data transfer is up and running, and is achieving a respectable degree of saturation of the link.

EGO Cascina (PI)

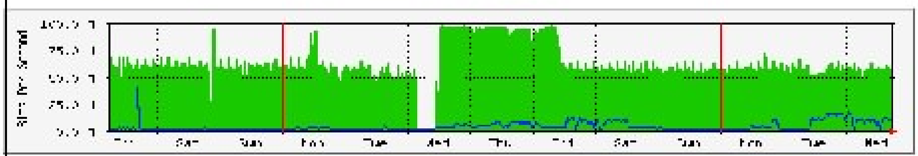
System: RT.PI1 in
Interface: fe-4/1/0 (43)
IP: rtg-ego.pi.garr.net (193.206.136.25)
Max Speed: 100.0 MBits/s (propVirtual)
BGA: 6.0 MBits/s (propVirtual)
The statistics were last updated **Wednesday, 6 June 2007 at 17:38**, at which time **'RT-PI1-RE0'** had been up for **244 days, 21:56:04**.

`Daily' Graph (5 Minute Average)



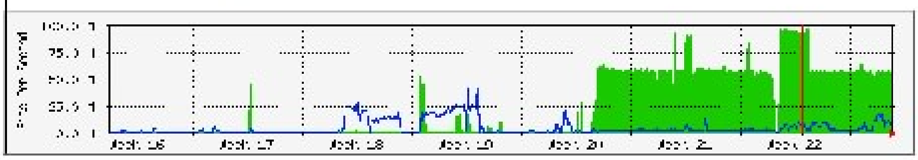
	Max	Average	Current
Bits/s:	93.2 Mb/s (1516.8%)	55.4 Mb/s (902.0%)	54.1 Mb/s (880.9%)
Bits/s:	18.1 Mb/s (295.1%)	8175.6 kb/s (133.1%)	9894.8 kb/s (161.0%)

`Weekly' Graph (30 Minute Average)



	Max	Average	Current
Bits/s:	97.0 Mb/s (1579.3%)	60.5 Mb/s (985.2%)	48.2 Mb/s (784.1%)
Bits/s:	40.9 Mb/s (666.4%)	3815.5 kb/s (62.1%)	8711.1 kb/s (141.8%)

`Monthly' Graph (2 Hour Average)



	Max	Average	Current
Bits/s:	96.6 Mb/s (1572.4%)	23.8 Mb/s (387.9%)	56.3 Mb/s (915.6%)
Bits/s:	47.8 Mb/s (777.8%)	4266.7 kb/s (69.4%)	10.9 Mb/s (176.7%)

4.1.2 Bookkeeping database

A prototype database, based on mySQL, has been developed, and code to feed it automatically, monitoring the filling up of data directories, has been set up and tested. The database can store the location of the frame data files, as well as various tables of metadata, in particular epoch vetoes. A simplified interrogation interface, for the non mySQL expert, has been also prototyped. Routines for feeding tables produced by the Physics groups have been developed, and one of the noise monitor (HACR) is already saving its triggers in this database.

The database is currently being relocated on a EGO computer, and a beta version should be released to the physics groups in about one month.

4.2 Offline computing in Bologna and Lyon

We recall that the off line computing for Virgo is performed in part in Cascina (as long as the on-line farm is not fully booked for on-line analysis) and mainly in the two computing centers of INFN and IN2P3 located in Bologna and Lyon.
We recall also that the two computing centers use different accounting units for the CPU usage. In order to unify and compare the impact of the Virgo activity in the two centers, we assume the following conversion factor:
1 CPU @ 1GHz ~1 kSP2000.
480 UI of CCIN2P3 UI ~ 1kSP2000.day

4.2.1 Virgo at INFN Tier1-Bologna

We report here about the January – May 2007 activity

Computing
The CPU cycles were spent on pulsar searches, burst searches triggered by GRB signal, and optics simulation
The total number of jobs submitted (grid+non grid) was 8443, for a total normalized CPU time of 1233 days.
The CPU consumption in kSPECint 2000 was

- jobs submitted under grid->271 kSI2k*day;
- jobs sub. under MPI->240 kSI2k*day;
- jobs sub. under standard batch scheduler -> 518 kSI2k*day;

Data storage
The older Virgo data, which was still stored on spinning media (24 TB under NFS, 6.7 TB under GPFS), is being moved to the CASTOR mass storage. This activity concerns the Commissioning C0-C7 runs, as well as the Engineering E1-E4 runs, including the 50Hz and trend data, as well as some user space.
The NFS volumes freed will be released by Virgo and transferred to the tier 1 management.

In exchange, large GPFS areas have been made available for recent data, in particular for the WSRs, the VSR1 data, as well as the LIGO processed data of the S5 run, which are being stored since May 18th.

The WSR runs archive in Bologna needs also to be restored on spinning media (GPFS), the most convenient way it to transfer back this data from Lyon to Bologna.

We are currently using about 26 TB under GPFS, and have about 60 TB available, which can roughly cover the needs for about 100 days of run time.

4.2.2 Virgo at CCIN2p3 - Lyon

Lyon computing centre (CCIN2P3) is used to store permanently the Virgo data (all streams recorded during data taking periods). Since the beginning of the joint LSC-Virgo S5 SR1 data taking, Lyon stores the 4 additional processed data streams sent from Caltech by LIGO. CCIN2P3 is also intensively used for off-line data analysis. The main use of the computational resources is done by submitting jobs via standard batch queue (BQS). Since the beginning of 2007, the CPU consumption has increased compared to previous years due mainly to the burst search. Some pulsar jobs are also submitting through Grid.

3

We summarize the Virgo resources used in Lyon, as of June 6^{th} 2007

Storage:
67 TB used in HPSS for all the data taking periods
300 GB on disk for users

CPU:
Use of the CPUs since 2007 January 1st: 11040 kSI2000.day (our request for 2007 is 50000 kS2000.day). Virgo consumption represents 4% of the total CPU consumed by all the other experiments performing data analysis in Lyon.

4.3 The analysis activity of Physics groups.

We recall here that in Virgo we have organized five Physics groups having different scientific targets of data analysis:

Burst signal search
Coalescent Binary signal search
Pulsar signal search
Stochastic background signal search
Detector Noise study

To these groups we need to add the *h-Reconstruction* which takes care of calibrating the data and of removing some of the known disturbances.

4.4 Calibration and h-Reconstruction

Since the first WSR1, discrepancies had been found between the expected behaviour of the actuators, and the actual one. In particular, large differences, of the order of 40%, when comparing the calibration of the differential signal resulting from acting on either of the two arms, as well as discrepancies, of the order of 20%, between the expected SNR of hardware injected signals and the SNR measured by the analysis algorithms.
The comparison of h-Reconstruction and calibration as well evidenced inconsistencies that could be attributed to some frequency dependence of the mirror actuator gain.

Some of the commissioning shifts have been therefore dedicated to re-measure the mirror actuator gains. In this process, a faulty DAC has been detected and replaced; this was the culprit for the large difference of the calibrations using either of the arms.
Moreover, a frequency dependent effect in the mirror actuator response has been observed and characterised; this appears well explained by Eddy currents in the reaction mass.
Thanks to these activities, the errors in the range 40 Hz-1 kHz have been reduced from a maximum of 40% to 10-15%.
The analysis of calibration data has been automatized to allow monitoring the calibration stability during the science run.

The reconstruction has been improved by taking into account this frequency dependence effect as well as the PR correction signals, and is running online during the science run.
The online version has been upgraded several times before and during the run, to provide a more accurate handling of the control signal at low frequency and to cope with the modifications of the control loops made before the run.

3

The accuracy of the reconstruction at low frequency during the first part of the run was adversely affected. A reprocessing of these data is ongoing to fix this effect.

More information can be found at:
https://workarea.ego-gw.it/ego2/virgo/data-analysis/calibration-reconstruction

4.5 Burst Group

The Burst Group activities are as usual manifold: analysis of the run data, definition of vetoes, network analysis with LIGO and with resonant bar detectors, as well as continuation of previous work on development/improvement of filtering methods for burst detection.

4.5.1 Analysis of C7 data

Two single detector analyses of C7 data have been completed: an analysis triggered by the GRB050915a that occurred during the run and one blind “all-sky” search in the frequency band [150Hz, 2kHz], taking benefit of the deep understanding we have of the data due to all previous detector characterization studies we made. No plausible event has been found and both searches have set upper limits concerning GW events (in particular for released energies). Papers are in preparation.

4.5.2 Analysis of WSR data

During the last months we have focused on WSR7-WSR10 data (better and more stable data). We first began to study the possible coincidence with GRB070219 that occurred during WSR9. Same procedure as for the C7 GRB is being applied. Preliminary results have been shown in the LSC-Virgo May meeting.
In parallel a huge effort has been devoted to the veto studies, in particular to a veto primarily built in order to kill the so called “dust” events that pollute burst and binaries analysis. These events are attributed to dust particles crossing the beam, and cannot be associated to any external (environment) channel trigger. However, they are in general seen in both phases of the dark fringe port (ACp and ACq channels) while a true GW event should be seen only in the right phase (ACp for Virgo). The veto is then based on a comparison of signal strengths (if coincident) in both ACp and ACq channels. This is a delicate study and the veto safety has to be assessed, since the separation between ACp and ACq channel is of course approximate. Special loud hardware injections have been performed for this purpose. A veto definition has been finally given with very conservative parameters.

4.5.3 Analysis of VSR1 data

Since the beginning of the run the data have been analysed online with the Qpipeline with result summary every five minutes including a time-frequency map of the loudest event. Other (off-line) pipelines are routinely running on the data (Peak Correlator for instance).
From the burst analysis point of view, the quality of the data up to now is quite good. The data are clean without large outliers in the event distribution as in the past. This will ease of course the physics analysis. More detailed studies are ongoing.
Some GRB have been coincident with the run. One seems promising for a coherent analysis with LIGO since its visibility is quite good in all the interferometers. We plan to set up a dedicated coherent analysis for this GRB in the near future.

4.5.4 LIGOVIRGO joint working group

This is an activity started before the beginning of the data sharing provisions, and actually it was the last step of the preparatory joint studies, which has been successfully completed (“project 2b”). The goal was to analyse a set of 24h of coincident data from the 5 instruments (the 3 LIGO interferometers, the Virgo interferometer and the GEO interferometer) with secret time shifts. The data set corresponds to the WSR1 period. Despite Virgo was not yet at

3

its design sensitivity and could not compete at least with the two 4km LIGO interferometers, this project was meant to be a methodological one, to set up the tools needed for a real complete analysis from trigger lists generation to the assessment of an upper-limit. The Virgo Power Filter pipeline has been chosen for this study. Trigger lists have been generated, injections have been performed so that the efficiency of the network (in coincident mode) has been set for a number of target waveforms. The very last step (physics results i.e. upper limits setting) has not been performed though, since it is not interesting (not competitive with previous limits) and since now we turn our forces to the analysis of VSR1 and LIGO data.

4.5.5 Virgo – Resonant bars collaboration

A paper detailing the joint analysis of 24 hours of data taken during Virgo C7 and including Auriga, Nautilus and Explorer data is in the final stages of preparation. Moreover, a cross-correlation method is being developed and tested using Auriga and Virgo-C7 data. There seems to be some improvement (albeit modest) with respect to previous (coincident) analysis.

All the burst activities are detailed in the Virgo working area pages:
https://workarea.ego-gw.it/ego2/virgo/data-analysis/burst/burst-working-area/

4.6 Coalescing binaries group

Highlights from the CB group activity in the past six months are summarized here.

Since the end of January 2007, the Virgo CB group has been operating jointly with the LSC inspiral group, forming what is now called the "LSC-Virgo CBC group". Common telecons are held on Tuesdays, while specific telecons are also held on Mondays to discuss specifically the Virgo CB data analysis activities.

Two articles have been written and submitted to CQG as contributions to the GWDAW 11 proceedings. One about the general status of CB searches (presented as a talk at the workshop), and one about a way to improve the timing precision for inspiral signals (presented as a poster at the workshop).

The effort to develop code able to perform network coherent analysis for inspiral signals has been pursued. Extensive simulations have been performed to study the precision of the source direction reconstruction achieved by the coherent method. Some results have been presented at GWDAW 11 (as a poster) and at the Moriond conference (as a talk). Work is in progress to fully characterize the method and to do a fair comparison with coincidence analysis methods.

Developments to extend the CB search at higher mass, beyond the BNS systems, have been going on. More specifically, tests to use EOB templates in the search instead of PN templates have been done, and tools to generate template banks appropriate for BCV templates have been developed.

Prospective work to assess the benefits of using templates including amplitude corrections has been done. Some group members contributed to a study done in collaboration with LSC members about coherent parameter estimation based on such templates, a work which was presented at GWDAW 11.

A lot of effort was devoted to analyse the pre-VSR1 data, namely the data collected during the week-end science runs (WSR1 to WSR10). This was done mostly in the perspective of characterizing the detector and providing feedback to the commissioning team. Some of the veto studies done in that framework were done in collaboration with the burst group. In

3

addition to the detector characterization analyses, a dedicated search targeted at a gamma ray burst which occurred during WSR9 is also going on.

In the past weeks, the group has obviously been committed to the VSR1 data analysis. This involves running pipelines online and providing the associated monitoring available to scientists on shift to assess the quality of the data. The related detector characterization and veto studies for the run are also gearing up.

The BNS search was identified as appropriate for a joint search with the LSC-Virgo detectors in the coincident times of S5 and VSR1. The project is currently being initiated through an exercise performed on data taken at the epoch of WSR8.

4.7 Pulsar Group

The activities have been divided in several aspects: continuation of the work on Virgo data and Virgo search methods, start of the joint activity with the LSC Continuous Wave group, as well as work on the software for distributed computing.

4.7.1 Virgo data analysis and search developments

Coincidence search among periodic source candidates with the Virgo data, presented to the GWDAW11 in Potsdam. We settled the pre-analysis did on the data of the C6 and C7 for the search of periodic signals in the band between 50 Hz and 1050 Hz. We found about 923 million candidates from C6 and 319 million candidates from C7, finding about 2700000 coincidences.

Software injections in C7 data, to calibrate the analysis. Three different studies were completed:

1. one pilot study with signals without spin down.
2. One simulation with 500 signals many of them with non-null spin-down.
3. One simulation with the same signals, but with a dilated time scale, in order to cover, with the C7 data, about one year (dilation factor 80).

Fast simulation program: we developed a new faster simulation program more than 100 times faster than the older one, with frequency domain procedures.

New cleaning procedure: the old rough cleaning procedure that excluded highly disturbed narrow bands, has been replaced by a procedure that takes into account a priori information. Applying it, we found unknown frequency harmonics at multiples of 1 Hz, 2.632 Hz, 19.231 Hz and 41.618.

WSR analysis: the WSR 7, 8, 9 and 10 have been analyzed, demonstrating that the new cleaning procedures is indeed more effective and safer for real GW signals.

More work on efficient candidate database: the work is in progress, in order to have faster coincidence algorithms.

4.7.2 Ligo-Virgo joint work

The activity is regularly reported and discussed during weekly phone conferences of the joint LSC-Virgo CW group.

SFT data exchange: Data in the short fft format have been exchanged, with the purpose of testing different approaches to data pre-processing and to compare the LSC and Virgo formats.

Ligo Hanford 1 data analysis started: we started the analysis of about 2 days of H1, coincident with the WSR10. The study has evidenced differences in the noise properties, which gave rise to analysis issues, that we are presently confronting.

3

4.7.3 Service procedures

Modification of the Supervisor: the software needed to run jobs in the distributed computing (GRID) environment has been upgraded to use new grid libraries.
Snag enhancement: the analysis environment has been upgraded with new possibilities in the group data management. In total we added or changed about 120 m-functions and more were upgraded (on the total of more than 1100+obsolete).
Compiled Matlab procedures: the main Matlab procedures for the pss production work were compiled (under Windows and Linux).

Most of the work is documented in the PSS_UG, and in reports available in http://grwavsf.roma1.infn.it/PSS/

4.8 Stochastic Background

The group is fully involved in the collaboration with the LSC. There are two scientists in Virgo dedicated to the stochastic activity, another one started to collaborate. A postdoc joined the group, though only part time.

- The preparatory activity on simulated data is completed. Report on the results can be found on the proceedings of GWDAW 2006 workshop, and in several presentations. In short, we validated three different basic analysis pipelines (matlab, c and c++ based) which give results in agreement with the theoretical expectations with a statistic based on the project1b simulated noise data (24 hour).
- The next step in our activity will be the analysis of the joint data which will be produced by the LSC/VIRGO collaboration. We are currently planning the steps of the analysis and the requested computational infrastructures.
- We plan to implement alternative strategies in the Virgo C++ pipeline, in particular filtering (adaptive or not) in the time domain, in order to address well known problems connected to non stationarity of noise in a innovative way. However there is no real progress in this issue from the last report.
- The simulation of a set of correlated streams for a Gaussian, stationary and isotropic model of stochastic background and an arbitrary number of detectors is fully contained in the Virgo code, has been tested on several cosmologically and astrophysically motivated spectra, and will be used for future software injections.
- Anisotropic models. We started the study of signal simulation. The new postdoc is expected to work both on this issue and on the detection problem.

The restricted Virgo/LSC group met two times in Pisa and Nice, as well as during the face to face meetings of the Virgo/LSC collaboration in Baton Rouge and Pisa.

4.8.1 Software

The implementation of code for simulation of anisotropic models is in progress. Documentation still needs to be improved. The main problem here is that presently only one scientist is working on this item.
The C++ pipeline will be applied to the analysis of real VIRGO/LSC data. As a preliminary activity we are testing the codes on the Bologna cluster. It seems possible to do the analysis also on a GRID farm: this possibility and the needed modifications to the code are currently under investigation.

4.8.2 Conferences and publications

The results of the group activity were presented at the last GWDAW. Some presentations are available which contain reference material for past results and future projects.

3

http://www.df.unipi.it/~cella/cantina/whelan-1180010512.pdf
http://www.df.unipi.it/~cella/cantina/2006_gwdaw11.pdf

http://ldas-sw.ligo.caltech.edu/ilog/pub/ilog.cgi?group=stochastic&task=view&date_to_view=03/06/2007&anchor_to_scroll_to=2007:03:08:05:11:28-gcella

4.9 The Noise group activity

The Noise group activity has been intensely interwoven with the commissioning activity so that most of the contributions were of immediate use to improve the interferometer performance.

Items studied specifically were the acoustic noise and tapping tests, with special reference to the Detection tower Brewster window. This activity was of support to the work of replacement of this window, replacement that hasn't brought yet the expected improvements. This kind of tests was also performed at the end benches, allowing to identify back scattered light that would reintroduce seismic noise into the interferometer arms and mitigate its effects.

Studies of nonstationarity are now done on a regular basis using a number of tools like NonStatMoni and Line Monitor, allowing to search for periodic noise sources, like low frequency oscillations.

The HACR tool, developed in GEO600, has been adapted to Virgo needs. It allows to search for excesses of noise in a time-frequency domain systematically over many channels. For example a strong oscillation of the BS mirror at 600 mHz would cause a noise excess seen at the 6 kHz mirror resonance.

The Q transform used in Ligo was applied to WSR9 data. Loudest events were studied in more detail, suggesting the presence of dust.

Now that VSR1 has started it is possible to perform noise analysis in a more systematic way. First indications of data quality come from the monitoring activity during the shift and will be extended thanks to the analysis of the non GW interferometer channels and environmental monitor signals. The systematic monitoring of some of the features of the remaining noise has started, looking for long term drifts to be correlated with environmental conditions.

4.10 Future DA activities in the framework of the LSC-VIRGO agreement

It is worth dedicating a section of this report to the collaboration with the LSC, which has begun in Fall 2006 with the search groups starting to merge, has continued through the science studies which led to start the data exchange in May 18th, and is now entering the era of full joint analysis.

We recall that a Virgo only or LSC only analysis does not exist anymore, with the exception of transient, legacy activities.

The science goals of the joint search groups are laid out together by Virgo and the LSC, and a joint white paper is in preparation for this purpose: a first draft is available at

3

http://www.lsc-group.phys.uwm.edu/ligovirgo/dac/whitePaper/main.pdf

to be issued as a first version in July 2007 and then finalized in Fall 2007.

This white paper describes the science motivations for the different searches, as well as the methodology used, and is meant to incorporate the plans for the different activities and the exploitation of the data.

The white paper also includes a description of the hardware and software infrastructure available for the analysis.

Although the DA activity is common, most of the Detector Characterization and of the development of Data Quality and Vetoes remains in the hands of the respective Collaborations, since instrumental features are best studied and characterized by respective detector experts.

This defines a first priority of all the Virgo DA groups: to produce a statistical characterization of the Virgo detector data, in a form suitable to be exploited by the searches.

Then the general goal is to make the best use of Virgo data, in a context which now includes five detectors at four different geographical locations, thus opening the way to sophisticated coincidence and coherent analysis.

The plans for the Virgo DA groups in the short term, that is during VSR1 and immediately after, can be summarized as follows:

- data from the VSR1 are to be analyzed with the purpose of characterizing its noise. This activity is also meant at measuring the machine progress after dedicated commissioning breaks.
- The VSR1 data will be searched for burst events: Virgo is as sensitive as LSC detectors at frequencies above 500Hz, but the search is likely to cover the full band. One or more joint papers are expected to result from the analysis of coincident VSR1 and S5 data.
- The VSR1 data will be searched for coalescing binaries in the BNS range, with component masses up to a maximum of 3 M. Despite the lower range of searches on Virgo data, the study is useful for improved coverage and for the development of the future strategy, which could include coincidence analysis and coherent follow-ups. A paper on BNS searches focused on the VSR1 – S5 data is expected from this activity.
- The search for a stochastic background using VSR1 data is meaningful in the upper portion of the frequency band, where the contribution of detector pairs involving Virgo is equal or better that the Hanford/Livingston one. The impact on the upper limit obtainable over the full band is relevant only for stochastic background models where higher frequencies are enhanced, while it is negligible for the simplest "flat omega" model. Nevertheless, data will be analyzed with the goal to publish updated upper limits. Moreover, the "radiometer" approach for mapping the sky stochastic GW background could be developed and tested. Papers or conference proceedings are expected also in this case.
- The pulsar group will first focus on the data characterization, cleaning the narrow spectral features; the actual searches are then strongly dependent on the sensitivity. At frequencies where LIGO detectors are significantly more sensitive, a search of continuous signals is not going to benefit from Virgo data. Nevertheless, the all-sky

[3]

search will be performed, and the candidate lists will be put in coincidence with those obtained on LSC data. At very low frequencies, for instance for the Vela pulsar, a targeted search for which Virgo is the most sensitive detector of the network is possible, and could result in a publication with unprecedented sensitivity.

In the medium term, that is during the next two years until the restart of Virgo+, the groups activity will be of course focused on finalizing the analysis of S5 and VSR1 data. There will be however other activities:

- the Virgo detector progress will be followed, and data taken during WSRs or more generally in data taking shifts will be analyzed with the purpose of a first data quality and sensitivity assessment, in order to provide feedback to the Commissioning and Detector crew.
- All the groups will work to get prepared for better data; this means upgrading the search methods for the situation in which the LIGO and Virgo detectors have similar sensitivity, and the band is widened.
- We expect Virgo to be operated as much as possible in "astrowatch" mode, that is acquiring science data whenever this is possible without competing with the Commissioning activity. The analysis of this data will be focused especially on epochs coincident with external triggers, like GRBs; the current understanding is that short hard GRBs are likely to be associated with coalescing binaries, while long GRB would be associated with supernova explosions, and this may reflect in the searches performed. LSC and Virgo data acquired for this purpose will be published to issue upper limits on the signals potentially emitted.
- The "astrowatch" data, albeit made of many separated short stretches, is in principle usable for pulsar searches. The priority could become high if in some portions of the band Virgo turns out to be more sensitive than LIGO detectors; this could motivate a targeted search if the combined statistics and sensitivity could grant an improvement over LIGO S5 upper limits.

  These considerations could be reversed. If during the Virgo+ upgrade the detector sensitivity were to become interesting even in a restricted frequency band, for instance around a known pulsar like the Crab at 60Hz, this could motivate a request to perform a dedicated science run, extended enough to publish science results.

In the longer term, we will have the e-LIGO/Virgo+ joint run, which will push the combined sensitivity to unprecedented levels: the Virgo goal is to participate to the analysis of those data on an equal footing as the LSC, with a good science reason: we want to continue developing and applying search methods which could be independent from the LSC methods, to boost the confidence in the combined results.
This is a tremendous effort in expanding the Virgo search groups capabilities, and is the main motivation for asking the Institutions to fund a significant number of post-doctoral fellowships that could start working now with this goal in mind.

3

5 Advanced Virgo

5.1 Introduction

Since the last STAC meeting the activity of the Collaboration has been focussed on the commissioning of the detector in order to meet the goal of starting the VSR1 on May 18th.
The activity of the working groups continued as described in section 1.2.
An “Advanced Virgo Workshop” will be held on June 14th to discuss within the Virgo Collaboration the status of the Advanced Virgo related activities and the plans for the next steps. The outcome of the workshop will be reported in the presentation to the STAC.

5.2 Working groups

In March P.Hello resigned as co-chair of the WG1 to focus completely on the coordination of the Burst group, as requested by the DA coordinator, and R.Flaminio took over. The complete list of coordinators now is:

- WG1: R.Flaminio (EGO), A.Freise (Univ. Birmingham)
- WG2: N.Man (OCA Nice), P.La Penna (EGO)
- WG3: M.Punturo (INFN Perugia), P.Puppo (INFN Rome)
- WG4: A.Gennai (INFN Pisa), N.Leroy (LAL Orsay)

The outcome of the WGs work is still not sufficient to start a real design, but a more intense activity is expected in the next months, now that the science run has started. Moreover, the hiring of a dedicated post-doc at Birmingham, within the 2nd EGO R&D program, is expected boost the work on the optical design, though not immediately.

A brief activity report for each WG follows.

5.2.1 WG1: interferometer optical configuration, sensing and control

The activity of WG1 covers in principle a very large area of research and development. The major task of the working group to date is to set early priorities for selected tasks and derive skeletons of optical design candidates.
The following list of core tasks which have to be studied with priority has been previously reported to STAC:
- control schemes for lengths and alignment control (including Signal Recycling)
- alternative lock acquisition techniques
- DC readout scheme
- dynamics of high-power, high-finesse cavities

We envisage that several people will invest more of their time in the optical design for Advanced VIRGO during the next months.
Meanwhile the following tasks were started or carried forward:
- The design of a small test facility (CALVA) has started. It will allow to test and investigate optical techniques for lock acquisition and potentially some electronic, mechanical and optical prototypes of subsystems designed for Advanced VIRGO.

3

- The investigation the interferometer behavior with Signal Recycling (SR) has started. The theoretical gains of using SR are well known. However, SR introduces a new complexity which can affect the design of many (optical) subsystems greatly. Since the VIRGO collaboration has no experimental experience with SR this must be a top priority for the simulation work.
- Evaluation of proposed or conceivable changes which will have an effect on the layout of the vacuum system. This includes the presence of wedges in the input test masses and the beam splitter as well as the introduction of non-degenerate recycling cavities.
- Simulation work regarding the use of non-Gaussian beam or higher order Laguerre-Gaussian modes. These are novel techniques which cannot be implemented without a great R+D effort by the VIRGO collaboration. The early simulation work aims at understanding the principle feasibility of these techniques in order to determine whether such an effort shall be started.

The current tasks are still in an early stage and are pursued independently. More work is required to reach a first skeleton design beyond a simple list of parameters. Further progress depends critically on the availability of key people. The process of hiring a dedicated post-doc at Birmingham University is under way.

5.2.2 WG2: laser and optics for high power

The objective of the WG2 group is to study the possible options for the high power laser and the corresponding input optics, in order to find the best solution for Advanced Virgo in terms of feasibility, performances, planning, cost and maintenance as well as simplicity or robustness.

- **Fiber laser**

In 2007, the experimental work with low power commercial fiber lasers in order to characterize their noise figures was started. The results for free-running noises are promising: they are slightly worse than the present Nd-YAG master laser, but a new way to prestabilize them, which promises a very high bandwidth, and then a very high gain is going to be tested (see the talk by N.Man at the recent Virgo/LSC meeting).

For the required specifications of these lasers the sensitivity curve projected for Advanced Virgo in the white paper is assumed as a reference, but inputs from the WG1 are needed as far as the modulation scheme is concerned. Actually if RF detection is kept for Advanced Virgo, the intensity stabilization of the laser has to be made in the detection range and around the RF modulation frequency, which is far more difficult and then the use of a pre-mode-cleaner as in Virgo, would be necessary again. In that case, a higher modulation frequency should probably be chosen, because it would become difficult to operate a high finesse per-MC at such a high power as 200W.
If DC detection is chosen, the new power stability requirements need to be estimated. They may become stringent, and some experimental work will be necessary too.

New kind of fibers called Photonic Crystal Fibers (PCF) have achieved recently very good performances in term of power standing, narrow emission linewidth, polarization control and beam quality. To explore the possibility of the PCF as amplifiers and mode cleaners a collaboration with French labs (XLIM from Limoges, Institut d'Optique from Orsay, ENSTA from Palaiseau) through a national contract has been started. The goal is to produce fibers suitable for passing high power lasers with good beam quality as well as to produce doped

3

fibers as high power amplifiers: 200 W average power, for CW and femtosecond lasers. To get familiar with the manipulation of PCF fibers, a fruitful contact with XLIM, that is designing and realizing the fibers, was established, as they have started to train a graduate student from Nice. The work in the next months will be to stabilize a low power commercial fiber oscillator as well as to test a large core PCF that will be produced by XLIM as amplifier. The remaining questions concerning these amplifiers are the management of non linear effects in high power operations as much as the polarization behavior of the fibers.

- **Input optics**

In the first half of 2007 the activity concerning the input optics was mainly concentrated on components which would be employed with the present reference configuration: solid state laser, in-air input optics components, suspended input mode cleaner, suspended in-vacuum input optics components. In this framework, the R&D proposed by EGO, INFN-Pisa and INFN-Naples, intended to test materials and devices using a commercial high power laser (a 200 W fiber laser), has started and is in its assembly phase. In particular, concerning thermal effects in Faraday isolators (either in air and in vacuum), a lot of simulation activity of thermal lensing and optical isolation loss has already started, and is being validated using for the moment an available low power laser. The components for the assembling the test facility will be available in summer 2007. The plan is to start soon testing the behavior at high power of a Faraday isolator, both in air and vacuum, and in particular to verify the possibility to use compensation of the thermal lensing effects using passive compensating crystals (DKDP).

A very fruitful exchange of information has started with the researchers working in LIGO on the same items. This collaboration has largely facilitated to clarify our ideas about Advanced Virgo needs.

In the next months further effort is needed in specifying the requirements for the input optics components, in particular:

- EOM: modulation index, maximum insertion loss, maximum distorsion loss, maximum spurious amplitude modulation, modulation balance ;
- Faraday: specifications on required isolation, vacuum effects, maximum of insertion loss and thermal lensing;
- IMC: transmission, stability, geometric filtering, frequency and amplitude noises filtering, seismic isolation, acceptable level of scattered light;
- Telescopes: optical stability, seismic isolation, requirements on matching, insertion loss, AR coatings.

These points have to be part of the discussion concerning the interferometer optical configuration.

5.2.3 WG3: suspension and thermal noise issues

- **Monolithic suspensions**

The activity of the WG3 group during the first 6 month of the year 2007 has mainly dealt with the construction of a first prototype of the monolithic suspensions for the test masses

3

in Virgo+. The groups involved are Florence, Perugia and Rome. The work in this task can be divided into four main activities:

- the development of the procedure to suspend the mirror by silica fibres welded on silicate-bonded ears;
- the design and realization on the marionette and the reaction mass taking into account the new requirements related to the use of the fused silica wires;
- the "mirror shaking tests" to check the robustness of the fibers;
- the test of the mirror local control with the monolithic payload;

The knowledge acquired in the Virgo+ framework will be extended to the case of the Virgo Advanced configuration in which the different dimensions of the new mirrors and the modifications of the super-attenuator chain must be taken into account.
In the first six months of the 2007 four assembly tests of the monolithic suspension with a dummy marionette and a dummy mirror have been carried on and the design of the marionette and the dielectric reaction mass have been defined. Moreover the shape of the ears shape and fibers tips has been chosen in order to optimize the mechanical coupling with marionette and the mirror and to reduce the mirror contamination during welding. During next month a new suspension test is planned in order to test the new ears design. Further information on this activity can be found in the detector coordinator report.

The WG3 is also following several R&D activities and the following, a description of the status of them is given.

- **Cleanliness requirements and mirror handling.**

In the Advanced Virgo configuration the use of a high power requires a careful control of the thermal effects on the mirrors. In this scenario the thermal lensing plays an important role and the mirror pollution is one of the most important factors that can spoil the mirror light absorption properties.
In the present configuration, the mechanical tuning of the superattenuator after the payload suspension is a complex procedure in which the mirrors are exposed to dust and pollution for a long time depending mainly on the geometry of the system.
The Virgo tower is designed with two different vacuum compartments: the upper part hosting the mechanical suspension and a lower part hosting the payload so that the mirror can be accommodated in a cleaner volume. These two sections are separated by an intermediate vacuum chamber, called separating roof, where four pots are bolted to enclose the coils attached to Filter 7 and steering the marionette.
The structure of the last stage suspension and its coupling to the Filter 7 could be reviewed in order to simplify the payload assembly procedure and shorten the suspension tuning phase.
A new design has been proposed, making use of a marionette reference mass hosting the actuator coils for steering the marionette. In this way it will be possible to remove the Filter 7 legs and modify the high vacuum chamber in such a way to improve the clearance for the monolithic payload assembly and to allow the installation of a laminar flow of clean air in this volume during the assembly phase.
Three guidelines of this R&D activity can be distinguished:

- design and study of the new mechanics;
- re-design and test of the hierarchical control of the last stage suspension system;
- modification of the Ultra High Vacuum chamber to improve the cleanliness and to reduce the operator presence within the tower bottom part during the payload integration on the suspension system.

3

This R&D study is being performed by the groups of Rome, Pisa and Lyon. A meeting was held in Lyon on February 2007 and another one is foreseen within the end of July 2007. The design study has started this year, and it is planned that the construction of the prototype should start on the second half of next year.

- **Electrostatic actuators.**

The Napoli group is carrying out the the development of electrostatic actuators. The introduction of an electrostatic actuation should give several benefits. The most significant are:

- increased optical and mechanical quality of the mirror: since there is no need to glue the magnets on the mirror surface, the contamination of the mirror is reduced and the mechanical quality factor is preserved;
- no coupling to the external magnetic fields. A residual coupling could arise at the level of the marionette, but in this case the residual noise requirements are more relaxed.

The main topics to investigate are shortly described in the following:

- design of the actuator: determination of the maximum force achievable for a given polarization voltage applied on the actuator; optimization of the distance between the mirror and the actuator; choice of the thickness of the electrodes in order to minimize the power dissipation that can generate thermal noise;
- design study of the reference mass, with the electrostatic actuator directly integrated in its internal surface to minimize the effect of misalignment between the actuator and the test mass;
- study of the actuator driving technique: DC and AC;
- reduction of coupling noises: evaluation of the coupling with external electric fields and reduction of the cross-coupling between the four actuator of the reference mass.

The Naples group has developed a model based on the image charge. In the first step of this R&D activity, that simple model was slightly improved to take into account higher order terms in the expression of the force between the actuator and the dielectric mass. On the basis of the model, and assuming a distance between the actuator and the mirror of about 1 mm, a simple 4-patterns actuator was designed.
The distance between the electrodes was chosen in order to allow a polarization as high as 2 kV, without perforating the dielectric substrates. This actuator was characterized using a suspended dielectric mass whose position is read by on optical lever. Good agreement between measurements and the model was achieved.
The influence of the electric charges that can be found on the test mass was experimentally studied. Since the actuator generates also a static electric field, it is clear that any unbalanced charge on the test mass produce an additional force on the mass itself. This effect is very well visible on the prototype and was reduced by using an AC driving.
The electrostatic actuator was used to lock a suspended Michelson interferometer in which only one mirror was controlled by the electrostatic actuator while the other one and beam splitter were both suspended on a bench controlled by coil-magnets pairs. The interferometer was locked by acting with the electrostatic actuator and leaving a the residual noise mainly due the residual angular motion of the suspended bench.

The next steps are the implementation of the additional degrees of freedom in the electrostatic actuation, i.e. θ_y and θ_x. The high voltage amplifiers are already available and the test should

3

start next month. Contemporarily to the test activity, a new kind of actuator was designed and realized to be used on a reduced scale dielectric reference mass of a suspended mirror.

5.2.4 WG4: electronics and controls

The activity of the WG4 is devoted to the preparation of the Electronic and Software part for the future of Virgo. This activity has started with the definition of a package inside the Virgo+ project, performed mainly by the LAPP and Pisa groups. These R&Ds were done to replace the timing system, to increase the computing power on the readout of the photodiodes, for the global control and for the Suspension control system, and to use less noisy ADC, DAC and coil drivers boards.

These different upgrades are needed to improve the noise budget of the technical noises which can limit the sensitivity in the low frequency bandwidth (<100 Hz). Our present system is already next to its limit in computing time and could not be able to support the new developments needed to reach the design goal for Virgo+.

The three meetings done since November were mainly devoted to the review of the R&D done and to check the limits of the new systems. With the present technology we can foresee a 40 kHz loop frequency and the main limitation is due to interrupt response. Future development in computer technology could increase our loop frequency. This information from the WG1 group will clarify better which new developments are needed for Advanced Virgo.

In the context of Advanced Virgo there are also some reflections done on the standards used in Virgo for the RF, cabling, analog electronics (we used 2 different standards, NIM and VME). This work is currently on going and will continue in the future with contacts with LIGO groups.

At last the working group will perform a check of obsolete systems which will need to be changed for Advanced Virgo.

The following months will see the validation of the R&Ds done for Virgo+, the installation on site and the commissioning. In the same time the group will continue its work of definition of the standards for the next upgrades.

5.3 Advanced Virgo Workshop

The Advanced Virgo Workshop will be held on June 14th. The agenda and the presentations will be available on the Advanced Virgo web page .
The goals of the meeting are the following:

- ❑ Summarize the work done so far in the WGs
- ❑ Overview the current R&Ds and present the new ideas
- ❑ Deepen the discussion on the Advanced Virgo plans
- ❑ Put in evidence the amount of work needed and the forces involved

[3]

5.4 Next steps

After the Advanced Virgo Workshop the work will be focused on the writing up of the Advanced Virgo Design Document, to be released by November 2007. A draft roadmap towards the goal has already been discussed among the Collaboration and presented to the STAC in the November ‘06 meeting. A slightly modified version follows:

- Oct. 06: release of the R&D document (done)
- Spring 07: hold a workshop where each WG presents the work done and a preliminary skeleton of the Design Document is presented (done)
- *Early Sep. 07: draft of the Design Document released for discussion in the Collaboration*
- *Fall 07: draft delivery to STAC*
- *Nov. 07: Design Document final version, including cost plan.*

The main concern remains the availability of manpower to carry the needed studies out. Anyway, the outlook is improving: the science run has started and there is a real wish of collaboration with LSC (from both sides). The WGs are pursuing contacts with LSC experts and this is expected to speed up the process.

3

6 Virgo/EGO Outreach

6.1 Site visits

Almost every Saturday morning, from October to whole May there was a group visiting the site, the large majority were high school classes and, among these, it is worth to mention College Segurane, from Nice. This was the first French school coming to Cascina, they enjoyed the visit and are planning to come soon with other classes.

6.2 Exhibitions

Since several years, in April, in Pisa, takes place an interactive scientific exhibition for school pupils: the Ludoteca Scientifica (http://www.ludotecascientifica.it/). In this frame a Virgo/EGO activity is always successful: small groups (five this year) of students are guided in assembling working laser interferometers, that are then donated to the schools for future usage. The components, for a value of about 100 Euros per interferometer are offered by the Pisa Physics Department in the frame of "Progetto Lauree Scientifiche".

6.3 Start of Virgo data taking

This is not in itself an outreach activity, but generated the most relevant media event of the last semester. It was a press conference to announce the start of the first Virgo Science Run, that occupied the whole day, May 22 (http://wwwcascina.virgo.infn.it/CollOrganization/PressInvitation-22May2007.htm). The high level of institutional representatives and the number of French and Italian journalists, together with several distinguished Virgo and LSC scientists contributed to the success of the event. The question answering time was very lively and has been extended during lunch time, during the site visit and beyond. We had interviews diffused on line and off line with Italian and French national radio. TV emissions and articles are still coming out on most diffused media.
As a consequence have been requested to write news of different length for CERN Courier, Aspera Newsletter and Asimmetrie (INFN magazine).

6.4 Virgo/EGO newsletter

"h – the gravitational voice" continues to be regularly published on the web, every quarter. Next issue, the first of the second year is due to come out on July first.

3

7 Annexe: Request for Data Analysis Fellowships in Data Analysis

Introduction

This letter is a request of help by the Virgo collaboration to the funding institutions, to manifest a shortage of human resources in the field of Data Analysis, which puts at risk the scientific exploitation of the Virgo data.

Background

Since its beginning, the Virgo project and then Virgo collaboration invested human and material resources to prepare for the analysis of the data, with the goal to exploit fully the Virgo potentialities.
To this end, four search groups were dedicated to search for the different signal classes, plus a reconstruction and calibration group, and a noise group. These groups have worked over the years to develop Monte Carlo codes, analysis libraries, detection pipelines, as well as carrying out the analysis of Engineering data, to test and develop of the search procedures, and to provide a feedback about data quality to the Commissioning scientists.
This activity not only produced several papers about methods and techniques, but has been regularly presented at international conferences, where the analysis of engineering data has been reported, and allowed to develop on-line and off-line analysis pipelines.
With the recent agreement with LIGO and the LSC, and the merging of the LSC and Virgo search groups, the chairs from the Virgo collaboration became co-chairs in the joint groups, thus demonstrating that the past activity earned us a good reputation even within the much wider LSC.
However, since the beginning of the LSC-Virgo cooperation, it has become dramatically evident that the human resources available for the analysis activity in Virgo are by far more limited than those available in LIGO.
With the start of the Virgo Science Run 1, and the beginning of data exchange with the LSC, the very few people dedicated to the analysis in Virgo are called to a large number of tasks, which include, but are not limited to:

- maintaining and running the Monte Carlo codes;
- performing the detector characterization and issuing data quality assessments;
- running the online analysis and scrutinizing its results;
- developing instrumental vetoes;
- running off-line searches for different source types;
- carrying out analysis follow-ups, including the investigation of loud events;
- performing the complex statistical studies needed to turn analysis raw numbers into physical upper limits or, eventually, event rates.

In a framework of full, transparent cooperation with the LSC, it is essential that Virgo contributes to all these tasks, because this is the way to keep a tight link between the people who built the Detector and the Data Analysis: a prerequisite for doing good science with the Virgo instrument.
In order for Virgo to keep in the new LSC-Virgo collaboration the role which was earned with the hard work and the large investments needed to bring the detector to its present state, it is mandatory that Virgo contribution to the analysis remains of the highest possible level.

3

Limits of the human resources dedicated to DA in Virgo

A survey of the Virgo search groups has demonstrated that each of them can count only on a small number of Full Time Equivalent scientists, ranging from 2 to 4.
It is particularly striking that the Virgo search groups are mostly formed by senior scientists, while very few are the PhD students, and even fewer the post-doctoral fellows.
By contrast, in the LSC most searches are led by post-doctoral fellows; they benefit from the experience, the guidance and also the real work accumulated over the time by more senior scientists, but are otherwise fully responsible of their research activity.
It could be thought that with the start of the science run, the Virgo people dedicated to the Detector could contribute to the Analysis. However, this is a misconception, since Virgo will have to be further commissioned, to bring its sensitivity closer to the design, and then upgraded; the expertises needed to carry out this ambitious program cannot be significantly diverted to contribute to the Analysis, and anyway their help is already needed for detector characterization and veto studies.
If the search groups are not enlarged, inevitably the analysis activities will more and more be led by LSC physicists, not only altering a balance that we would want to preserve, but also risking that Virgo data would not be exploited to the best of their potentialities.

Possible solution

It is our opinion that this shortage of resources can be confronted and successfully mitigated, by making available a significant number of post-doctoral fellowships, which could flank the senior scientists in the search activities.
It is also become evident over the years that these resources cannot be fully secured by means of ordinary channels, like the general calls for fellowships, at national or European level. These channels simply do not meet massive, urgent needs like we are having presently.
This situation has been foreseen for a long time, but the priority was, very justifiably, to carry out the Commissioning and reach a good sensitivity level. To this end, an exceptional effort was requested in the past to the Institutions, which provided several fellowships dedicated to the Detector. It is also thanks to this effort that Virgo is entering a Science Run, and now we are asking a similar effort to allow Virgo to fully exploit its potentialities.

Detailed requests

The search groups have determined the most urgent needs, which were translated in 9 profiles for the fellows, that we list below, group by group.

Burst group

The burst group aims at detecting, short, impulsive signals emitted by a variety of sources, including galactic supernovae, the final phases of coalescences, the ring-downs of black-hole excitations, as well as any un-modeled source of short GW signals.

Profile 1

The post-doc are expected to play a leading role in the search for burst GW signals such as those emitted by supernovae. This would include running search pipelines on the data, understanding the background, checking the search efficiency on simulated signals, and integrating the analysis in the framework of the joint LIGO-Virgo searches. The post-doc should in particular focus on background reduction (data quality issues and event by event vetoes) and network analysis with the aim of fully exploiting the LIGO-Virgo network.

Profile 2
The post-doc are expected to play a leading role in the search for burst GW signals such as ones emitted by supernovae. This would include running search pipelines on the data, understanding the background, checking the search efficiency on simulated signals, and integrating the analysis in the framework of the joint LIGO-Virgo searches.
The post-doc should in particular focus on background reduction (data quality issues and event by event vetoes) and targeted searches in coincidence with external triggers such as Gamma Ray Bursts.

Coalescing binaries group

The coalescing binaries group aims at detecting the emission of GW from the coalescence of compact objects, which result in signals having a duration from a few seconds up to minutes in the LIGO-Virgo bandwidth.

Profile 3
The post-doc is expected to play a leading role in the search for GW signals emitted by coalescing binary systems composed of two neutron stars.
This would include running the search pipeline on the data, understanding the background, checking the search efficiency on simulated signals, and integrating the analysis in the framework of the joint LIGO-Virgo searches.
Depending on the interests, the activity could be more focused on various aspects such as background reduction (instrumental vetoes or event-based vetoes), network analysis, or specific analyses like searching for signals associated with gamma ray bursts.

Profile 4
The post-doc is expected to play a leading role in the search for GW signals emitted by coalescing binary systems composed of two black holes or a neutron star and a black hole.
This would include running the search pipeline on the data, understanding the background, checking the search efficiency on simulated signals, and integrating the analysis in the framework of the joint LIGO-Virgo searches.
Depending on the interests, the activity could be more focused on various aspects such as background reduction (instrumental vetoes or event-based vetoes), network analysis, pipeline evolution to use various waveforms as templates for the search (including template bank generation aspects), or specific analysis targeted at systems with significant spin or large mass asymmetry.

Pulsar group

The pulsar group aims at detecting continuous signals emitted by distorted neutron stars. These signals are very weak, and require long integration times to be detectable, thus having to confront a range of physical (Doppler effect, source stability) and technical (detector stability) issues.

Profile 5
The fellowship holders is expected to play a leading role in the search for periodic gravitational signals. The candidate should have a good knowledge (and possibly experience) of the basic signal theory, the real gw antenna noise (for Virgo and Ligo interferometers), the astrophysical aspects of the search for periodic sources, of the main detection methods for periodic sources.

3

Depending on the interest, he/she could be dedicated to targeted searches of signals from isolated and/or binary pulsars

Profile 6
The fellowship holders is expected to play a leading role in the search for periodic gravitational signals. The candidate should have a good knowledge (and possibly experience) of the basic signal theory, the real gw antenna noise (for Virgo and Ligo interferometers), the astrophysical aspects of the search for periodic sources, the main detection methods for periodic sources
Depending on the interests, he/she could be dedicated targeted searches or to blind searches in a wide parameter space.

Stochastic background detection

The search for a stochastic background of gravitational waves of cosmological or astrophysical origin requires the study of a properly defined cross correlation between pairs of detectors. Under the standard hypothesis of a Gaussian and stationary noise the problem of finding the optimal cross correlation is completely determined. Both non linearities and non stationarities are expected in the data extracted from a real detector, and the determination of a sensible upper limit requires an accurate statistical characterization of the noise.

Virgo is starting to share its data with the LSC network of gravitational wave's detectors. The collaboration between several detectors is mandatory for the study of stochastic background, and the Virgo contribution is expected to be a relevant one both from the point of view of an improved sensitivity and of an improved robustness.

Profile 7
The candidate is expected to acquire first of all a good knowledge of the basic observational and phenomenological aspects of gravitational waves' stochastic background. At the same time she/he must become able to understand and use the available tools for the detection and the generation of stochastic background.
She/He will be directly involved in the application of the current detection pipelines to the data that will be shared in the framework of the LSC/VIRGO collaboration.

During its research activity she/he is expected to

4. apply the standard stochastic background detection procedures to real data, comparing the results with the expected theoretical predictions
5. design new detection algorithms, with a special emphasis on vetoing procedures connected to non standard noises
6. study the detection problem both for the isotropic and the anisotropic case, with a special emphasis on the characterization of the sensitivity that can be reached with the current sensitivities in the anisotropic case

Characterization of detector noise

The noise group has the purpose to provide statistical figures of merit about the noisy data produced by the detector. A correct understanding of the noise is indeed a pre-requisite for properly searching extraneous events in the data, potentially of gravitational origin, and detect them as different from the normal output of the detector.

3

Profile 8

The candidate is expected to acquire a good knowledge of the peculiarities of an interferometric detector of gravitational waves, from the point of view of noise peculiarities. This knowledge should be obtained experimenting on real data, coming both from the “physical” channels (dark fringe signals) and from environmental and control ones.

She/He will be involved in the application of the current data analysis tools to the real data of the Virgo interferometer.

During its research activity she/he is expected to

7. use existing diagnostic and statistical tools to understand detector's noise
8. design and implement new tools for the statistical characterization of the apparatus
9. be directly involved in the noise hunting activity of the Virgo experiment

Data conditioning and reconstruction

The calibration and reconstruction group takes care of translating the photo-diode read-outs into an equivalent gravitational deformation, taking into account and partially canceling the effect of the control loops which keep the detector at its working point.

Profile 9

The candidate is expected to acquire a good understanding of the detector, of its control procedures and of the techniques for calibrating its response and monitoring its sensitivity over the time.

He/she is expected to take crucial responsibility for one or more of these tasks.

She/he is expected also to gather and understand the needs and requirements coming from the search groups, and to respond to them with appropriate modifications and improvements in the reconstruction procedure.

Conclusions

In preparing this request for support, we were conscious of the effort asked to the financing Institutions, and also of the difficulty in finding a sufficient number of potential candidates; for these reasons we tried to be as minimal as possible with our requests.

We should underline, though, that with the start of the LSC-Virgo collaboration, and the data sharing, Virgo has become a very interesting experiment to work with in Europe, and therefore we expect high level candidates, not only from our field but from other ones, like from Astrophysics.

3