Virgo Progress Report
For the STAC and EGO Council

VIR-044A-07
October 26, 2007

Abstract

This report describes the Virgo activities and progress for the June to October 2007 period. It starts by a status overview and collaboration news, and is followed by six sections describing in more details the VSR1 run, detector, commissioning, data analysis, Advanced Virgo and outreach activities. These sections haven been prepared by the corresponding coordinators with inputs from various persons.

Summary

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1 Overview

1.1 Recent activities:

The highlight of the activity for the period covered by this report (mid-June to mid-October) is the first Virgo science Run (VSR1). VSR1 which was started in May 18th has been completed on October 1st at the same time as the LIGO S5 run. It has been followed by a two weeks post run activity for extensive calibration and various noise measurements in the VSR1 configuration of the detector.

The overall VSR1 duty cycle was 81% in “science mode” (data that could be used for data analysis). The down time has been due to the maintenance, commissioning, and various problems (see section on the VSR1 for more details about the run).

During the run, some time has been dedicated to commissioning activity (see section xxx for details) and the sensitivity improved, as this can be seen on figure 1 which shows the binary neutron star range (horizon averaged over all angles) as function of the time.

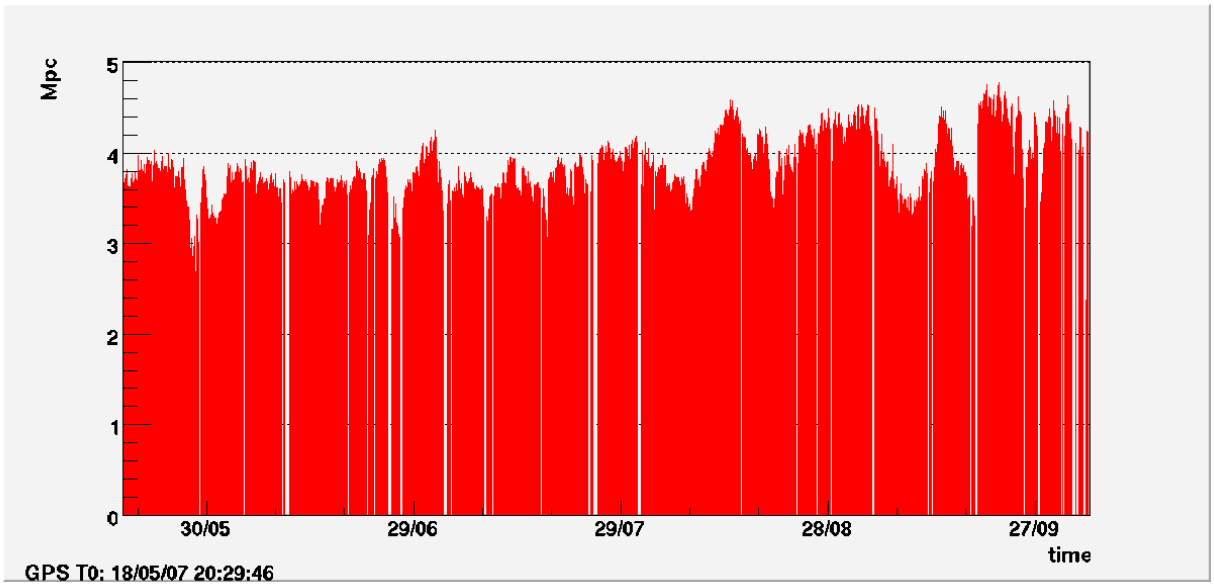

Figure 1 : Virgo binaray neutron stars range sensitivity at the beginning of VSR1 compared to the LSC detector sensitivities running at the same time

The data analysis people keep to be overloaded by the closer of the pre-run work and the analysis of VSR1 which is now done jointly with the LSC. See the data analysis section for more details.

1.2 From VSR1 to Virgo+

The commissioning activity to improved the low and mid frequency has restarted after the run. This period is expected to continue until the beginning of 2008. See the section on commissioning for more details.

The preparation of the different parts Virgo+ upgrades moved at different speeds (see the detector part for more details). We selected the upgrades which are mature enough for an installation during the first half of 2008 (Thermal Compensation system, laser power increase, electronic upgrade…). Despite the big effort and the results already achieved the engineering

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process of the monolithic suspension is not yet complete, which makes its installation unlikely for mid-2008, a date to be fulfilled to keep ***our goal to be back online at the same time of enhanced LIGO.***

Nevertheless ***the installation of a monolithic suspension during Virgo+ remains one of our goals*** since it provides an attractive scientific opportunity given the increase of sensitivity and since Advanced Virgo requires the monolithic suspension solution. Virgo+ is in fact the unique place to test the monolithic suspension and to explore the low frequency and low noise part of the sensitivity.

Therefore the baseline for the new payload (mirror + reference mass + marionetta) continues to be the monolithic suspension. The use of steel wires remains a backup solution. An examination of the current situation indicates that keeping the existing payload may be an acceptable temporary solution. This however would require the mitigation of the Eddy current. This could be achieved by simpler means, like caps on the magnets or even change of the magnets. Such a work may be simplified if it is possible to clean/protect the mirrors inside the tower, procedure that will be tried in November. It must be added that the current sensitivity measurement shows that the estimate made for the level of the Eddy Current effect was in fact over estimated, as we anticipated. To get an idea of the consequences of the payload choices, the figure 2 present the Virgo+ sensitivities for the different payload options and the following table summarized the impact on the different kind of sources.

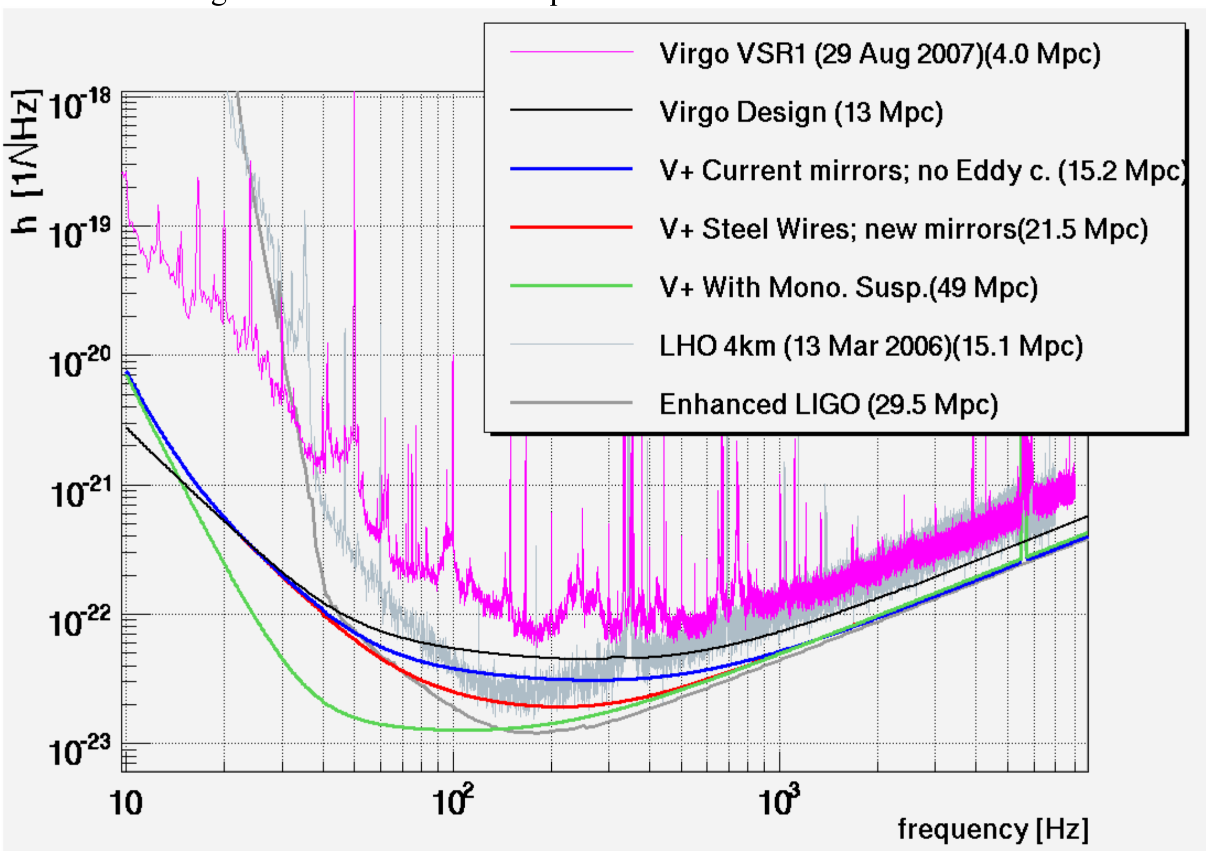

Figure 2 Different options for the Virgo+ mirror/payload choices. The V+ current mirror curve assumes that we can mitigate the possible effect of the Eddy current by means of caps on the magnet or by replacing the magnets. All the Virgo+ curves assume the new Thermal noise model ("Penn model"). The steel wires suspension curves assume a conservative number for the mirror internal noise (see footnotes on page 41 for details). Some technical noise based on an evaluation of the actuator noise have been added to the Virgo+ sensitivity. It should be underlined that these technical

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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...

Payload solution	Crab (60Hz)	BNS range	BBH range	Burst; 1kHz
Virgo design	$7.7\ 10^{-23}$	13 Mpc	63 Mpc	$7.5\ 10^{-23}$
V+ Current mirrors, no E.C.	$5.6\ 10^{-23}$	15 Mpc	76 Mpc	$5.1\ 10^{-23}$
V+ Steel Wires; new mirrors	$4.6\ 10^{-23}$	21 Mpc	109 Mpc	$5.0\ 10^{-23}$
V+ Mon Suspension	$1.4\ 10^{-23}$	49 Mpc	250 Mpc	$5.0\ 10^{-23}$

Comparison of the effect of the payload improvement for different type of signals. The CW Crab search requires the Monolithic suspension to make a significant step, the Coalescing Binary search benefit more progressively from the payload change, although the monolithic suspension provide a big step, while the high frequency burst search is basically not affected by the type of payload

This means that starting the second Virgo Science Run (VSR2) with the existing mirrors and reference masse is an option. This would probably allow a start of VSR2 earlier than mid-2009 and will give enough time to make a change of the mirror payload during the LIGO S6 run. The anticipated duration of S6 is also increasing since the installation of enhanced LIGO is well on track which means a start of S6 between March and June according LIGO estimate. At the other end the start of Advanced LIGO is delayed by the difficult negotiation between the US congress and the Bush administration for the 2008 US budget which means an extension of S6. The net result is the duration of the LIGO S6 run seems to be more in the 20 to 24 months, opening the possibility for a change of Virgo payload during S6.

Nevertheless, it must be stressed that our configuration for the start of VSR2 is still open and will be again evaluated in the next months taking into account the results of the current commissioning activity and especially the tests made for the cleaning, the estimate of the Eddy current level, the development of the mitigation procedures and the progress of low frequency part of the sensitivity. Let's also remark that the success of the monolithic suspension may require additional resources (people, additional test facilities) and adjustments in the sharing of tasks.

We finally remind that up to the start of VSR2 and S6, the detector improvements and commissioning activities have the priority over data taking for data analysis or "astrowatch".

1.3 Advanced Virgo

After a slow start due to the priority on Virgo commissioning, the Advanced Virgo activity ramped up. The Advanced Virgo coordinator and the working groups prepared the Advanced Virgo baseline and the preliminary Cost Plan and Project Execution Plan. ***We are submitting these documents to the EGO Council and are hoping that the council will approve the Advanced Virgo program and its baseline.***

The first expenses for Advanced Virgo are expected to be made in 2009. We will continue the Advanced Virgo preparatory work and will provide a more detailed budget ***for the 2008 EGO council meetings, during which we expect to get the approval of our first expenditures.***

It should be noticed that a start of the Advanced Virgo construction after 2009 would automatically delay it compared to Advanced LIGO which is now approved and for which the budget will be available in the next months.

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1.4 Collaboration organization- New groups

Another group, Padova-Trento, has shown interest for Virgo. These are physicists working on AURIGA who are bringing to Virgo their expertise in data analysis and detector characterization. After discussion within the collaboration, their application for membership has been accepted during the collaboration meeting of September. This is the fourth groups joining the collaboration during the last two years, the total number of group is now 13.

1.5 External collaboration

The close collaboration with the LSC is on-going, with especially the joint data analysis working group. Exchanges on technical topics continue (coating, thermal compensation, charging…). We had joint collaboration meetings in July and at the end of October.

Work is ongoing the better define the procedure to follow when there will be a discovery, from the different step of assessing the event to the choice of the publication journal.

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2 VSR1 Organization and Main Statistics

2.1 Introduction

The first *Virgo Science Run* (VSR1) has been performed in the period from Mat 18th 2007 at 23:00 LT up to October 1st 2007 at 07:00. The VSR1 has been carried on as a scientific data taking in coincidence with the LIGO S5 run, involving GEO600 (only during night time) and the three kilometric baseline North American detectors in Hanford (H1, H2) and Livingston (L1). The organization of VSR1 was developed in the context of a dense preparatory work within the "*Virgo Run Planning Committee*" (RPC) and the "*Joint LIGO-VIRGO Run Planning Committee*" (JRPC). All the foreseen activities that could have had an impact on the duty cycle has been previously discussed and planned, and a strict joint LIGO-VIRGO run coordination has been also established.

2.2 VSR1 Organization

The goal of VSR1 has been established to keep the detector in "*Science Mode*", optimizing the joint detection with LIGO, and maximizing the detection coverage during the unavoidable maintenance and commissioning interruptions. The run organization had to make plans in order to guarantee satisfactory detection efficiency, following the right procedures to acquire and maintain the ITF lock and monitoring the detection performances. Particular care has been taken to guarantee the exchange of information, concerning the detector status and short-term plans, among LSC and VIRGO run managers.

Following the experience of the previous short term scientific data takings of Virgo, it has been decided to organize the VSR in 8 hours shifts, requiring the presence of at least 2 people: one operator and one scientist. The main task assigned to the operator was to run the interferometer using the "*automated locking procedures*" (ALP). The scientist task was to monitor the quality of data taking, using the available on-line data-analysis tools.

The run coordination has been attributed to weekly run coordinators appointed by the run organizer. A great part of Virgo and EGO members have been called to participate to the shifts, according to the fraction of authors in the Virgo papers author list.

VSR1 has consisted of an overall amount of 406 shifts (3248 hours) involving effectively 7 EGO operators and about 110 scientists from the whole Virgo collaboration (about 76% of members of the author list in May 2007). The shifts have been planned in two different moments. At first a limited period of about 4 months, from May 18th 2007 at 23:00 LT to September 21st 2007 at 07:00 LT, was taken into consideration. This period of almost 18 weeks consisted of 376 shifts, with the direct participation of 12 groups (EGO, INFN-Firenze/Urbino, ESPCI/LMA, LAL, LAPP, INFN-Napoli, NICKHEF, OCA, INFN-Perugia, INFN-Pisa, INFN-Roma1, INFN-Roma2). The percentage distribution of the shift assigned among the various groups is shown in Figure 3.

At the beginning of September it was decided to extend VSR1 for a period of 10 days, up to October 1st 2007 at 07:00 LT, in order to make its end to be coincident with that of S5. The remaining period of VSR1, from September 21st 2007 up to its end in October 1st 2007 at 07:00 LT, has seen the participation of two new coming Virgo collaboration groups (INFN-Padova/Trento and INFN-Grenova). The percentage distribution of the assigned shifts during this last period is visible in Figure 4. As evident the assignment criterion considered in the

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first part of the run was relaxed in order to allow a significant participation of the two new groups.

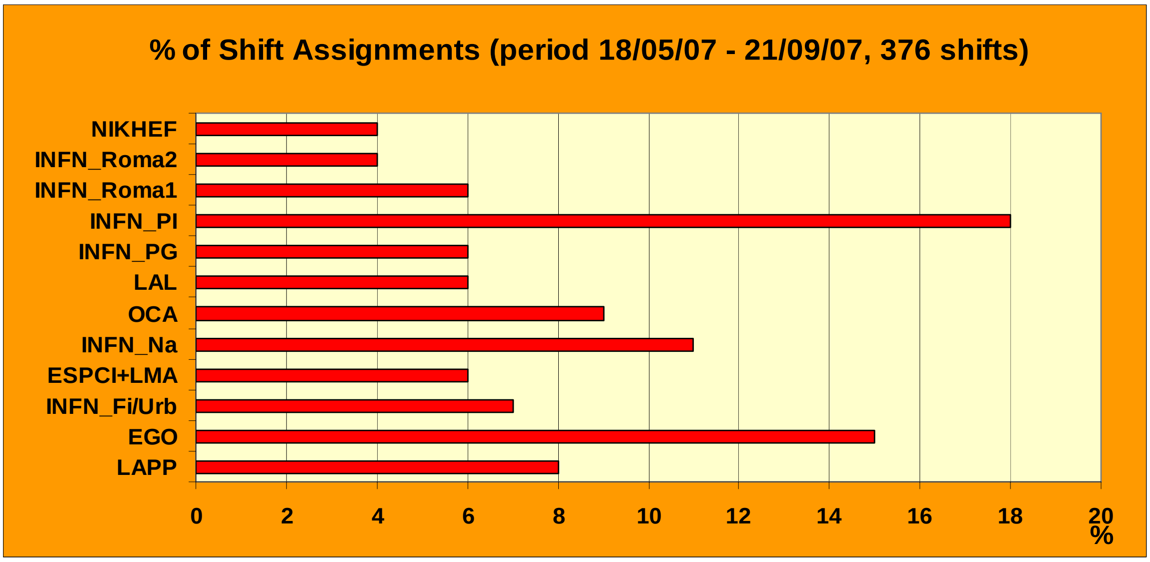

Figure 3 Percentage distribution of the shifts assigned during the period 18/05/07 – 21/09/07

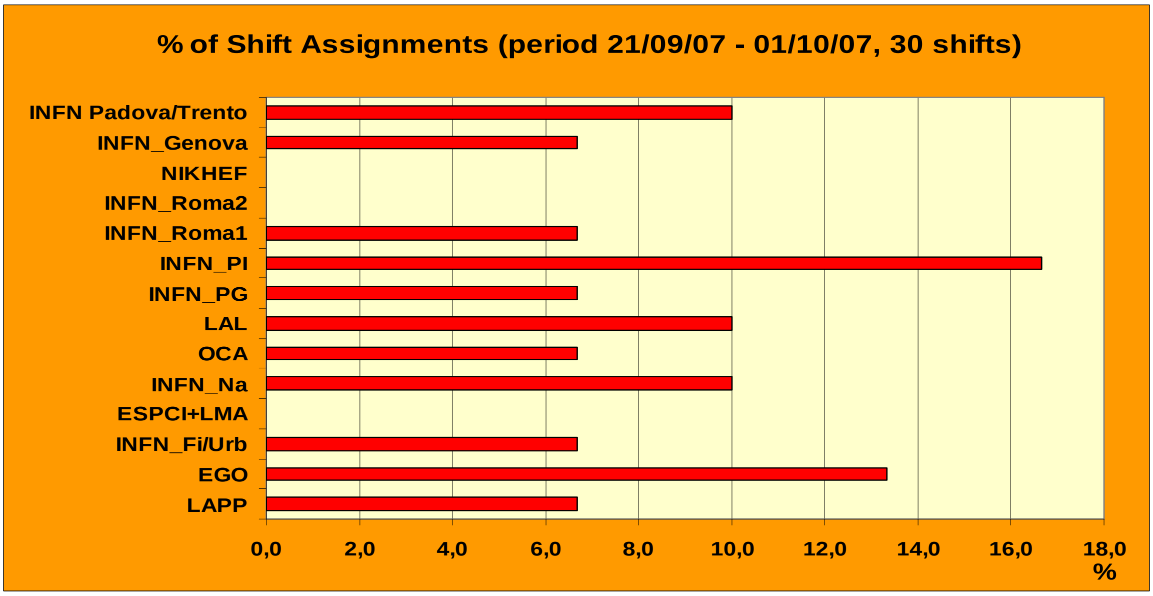

Figure 4 Percentage distribution of the shifts assigned during the period 21/09/07 – 01/10/07

It is worth mentioning also the participation to VSR1 of 19 run coordinators. The most of them have been in charge for one week period, coordinating all the long term planned activities and orienting the necessary short term actions of the on-call subsystem experts.

Trying to minimize the recovery time from possible detector failures it has been foreseen the presence of experts permanently on-call for 11 Virgo ITF subsystems (Alignment, DAQ, Detection, Electronics, Locking, Global Control, Laser & Injection, MSC, On line Computing & Network, Software, Suspension Electronics &Software), and 4 EGO site services (Network & Global Security System, Site Infrastructure-Conditioning, Site Infrastructure-Electronics & Software, Vacuum)

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During VSR1 only a limited number of actions have been allowed, such as calibrations, noise budget measurements, hardware injections, and some periodic maintenance and occasional commissioning breaks. In particular the maintenance activity has been limited to a weekly periodic time window of about 4 hours, for a total amount of about 80 hours. The commissioning activity also has been limited to a maximum of 25 hours each month. Therefore these two activities together have been foreseen to last for a minimum of about 5.6% of all the available run time.

2.3 VSR1 Statistic

During VSR1, as visible in Figure 5 and in Figure 6, Virgo has shown a quite satisfactory long term robustness, reaching at the end an integrated *Science Mode* duty cycle of about 81% and a Locking duty cycle of about 84%. Considering the net available detection time, subtracting the foreseen maintenance and commissioning dead times, the *Science Mode* and *Locking* duty cycles could be respectively rescaled to the values of 86% and 89%.

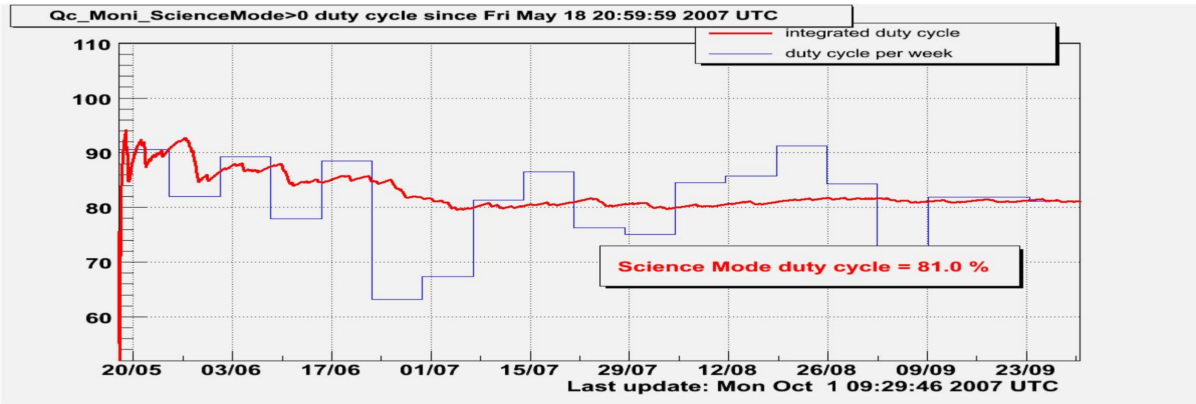

Figure 5 Trend of Virgo Science Mode duty cycle throughout all VSR1

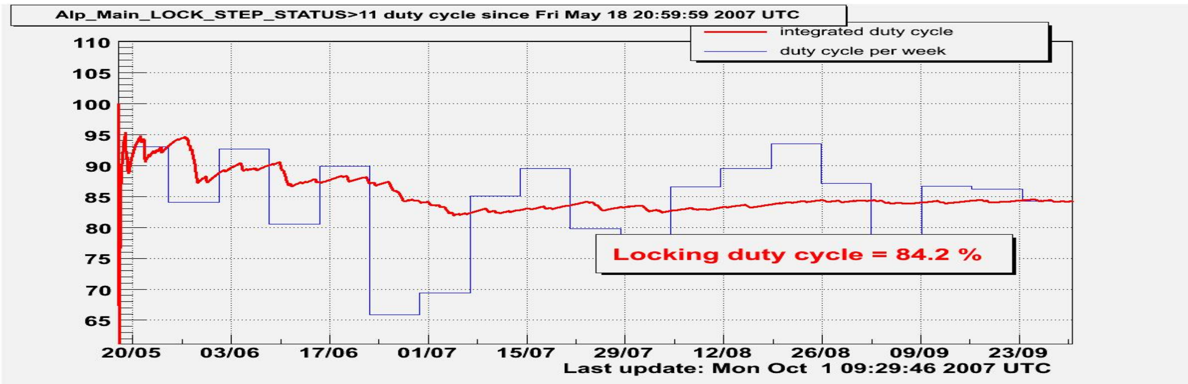

Figure 6 Trend of Virgo Locking duty cycle throughout all VSR1

A representation of the lock and unlock durations is shown in Figure 7. The average duration of the locking periods has been of about 11.7 hours, while the average unlock period duration has been of only about 2.4 hours. The maximum locking duration has been of 94.3 hours, while the maximum unlock duration has been of 17.1 hours. The average time required to lock the ITF and achieve the Science Mode status has been of about 30 minutes, the time required to recover from the thermal transients and to balance the beam sidebands resonating in the recycling cavity.

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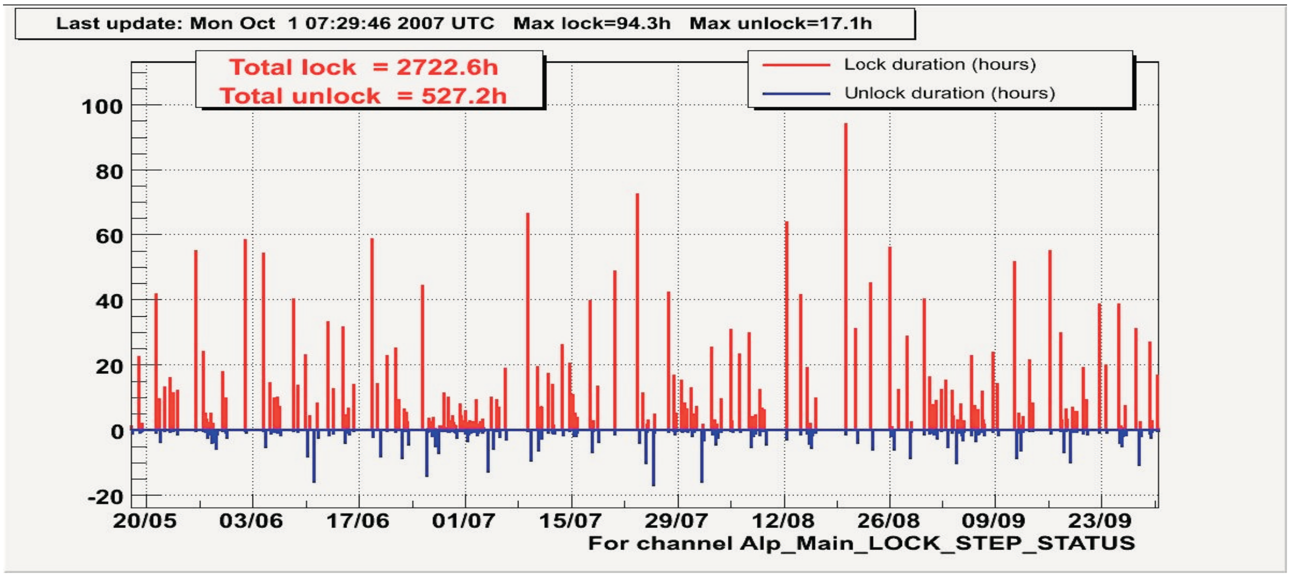

Figure 7 The time trend of VSR1 lock (upper red bars) and unlock (lower blue bars) period durations, in hours.

During VSR1 there have been 229 unlocks. A good indicator of the long term detector robustness is represented by the daily rate of these unlocks. In Figure 8 the time trend of the daily rate of unlocks from *Science Mode* configuration is shown.

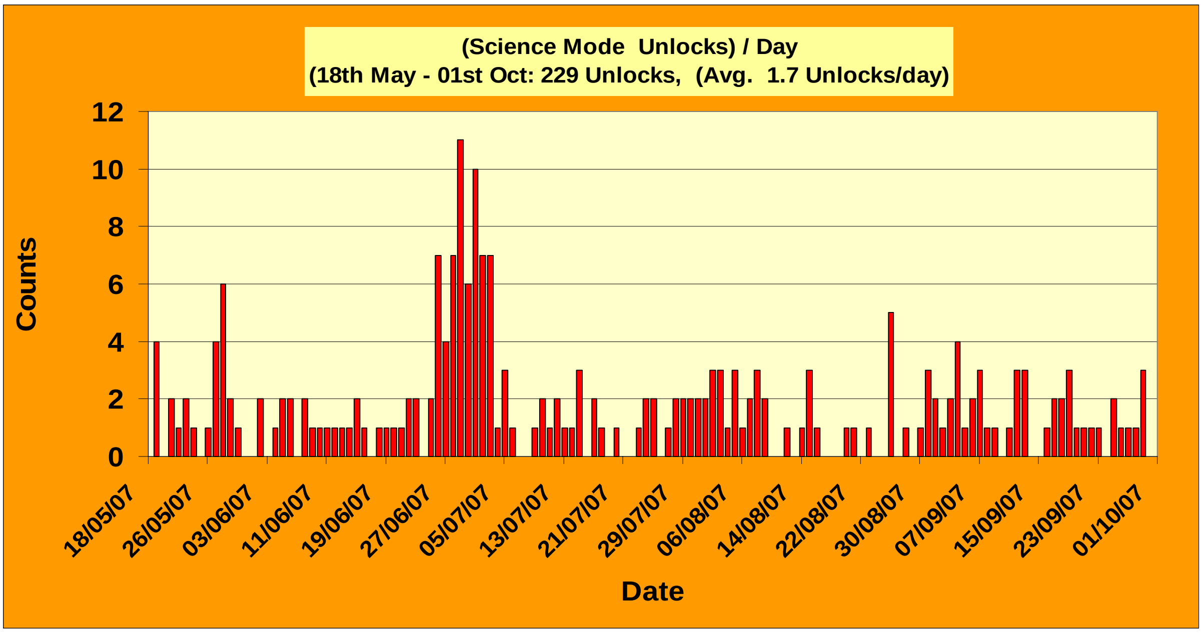

Figure 8 Time trend of the rate of daily unlocks from Science Mode

During VSR1 the average unlock rate has been of about 1.7 unlocks per day. A substantial deviation from this rate is immediately evident. It is almost all concentrated in the period at the beginning of July when a great number of fast unlocks of the laser injection system occurred, and has almost disappeared when the commissioning activity has solved this problem.

Almost the 83% of the 229 VSR1 unlocks have been understood and catalogued. The percentage distribution of the different unlocks events and of their corresponding total recovery time is visible in Figure 9. More than the 20% of unlocks have been caused by fast unlocks of the laser injection system. These events have involved the 7% of the total unlock period and, as already observed, their occurrence has regarded a relatively short time period. On the other hand the 12% of unlock events have been occurred during the periodic maintenance and commissioning activities, but their recovery time has occupied about the 33% of the total unlock time. Almost the 14% of unlocks have been caused by crashes of the real time global control (GC) system and has required the 9% of the total unlock recovery time.

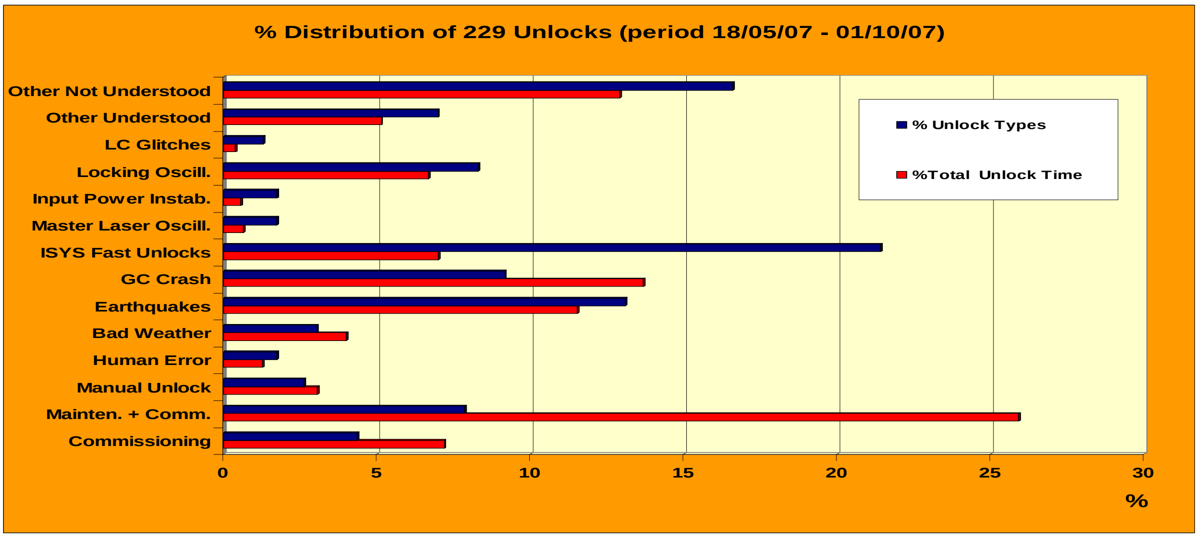

Figure 9 Percentage distributions of different unlock events (blue bars) and of their respective total duration (red bars).

Instabilities of the locking control loops have caused about the 8% of unlock events, absorbing the 7% of total recovery time. The unlock caused by heavy environmental conditions such as earthquakes, thunderstorms strong wind and see activity accounted for about the 16% of the events and the 15% of the total recovery time. Some commissioning interventions focused on the upgrade of the suspensions isolation, with the implementation of a new Global Control Inverted Pendulum Control (GIPC), have achieved, in the second half of VSR1, a better immunity against earthquakes and microseism.

2.4 VSR1 Performances

The performances of Virgo detection during VSR1 have shown a substantial increasing trend. Even if the occasion to make commissioning interventions have been limited by the higher priority of data taking, it has been possible to operate in order to achieve increasing strain sensitivity. It has been shown that also long term observations with stable detector configuration and status have been capable to suggest significant actions to upgrade the detector.

In Figure 10 is plotted the time trend of the average oriented NS-NS inspiral range during VSR1. Starting from a horizon initial value of about 3 Mpc the detector has progressively reached a horizon of about 4.5 Mpc.

The comparison of the Virgo strain sensitivity at the beginning and at the end of VSR1 is shown in Figure 11. The improvements in the low frequency region below 100 Hz are mainly due to upgrades of the locking common arm control loop and the attenuation of the excess noise from piezoelectric actuators on the suspended injection bench.

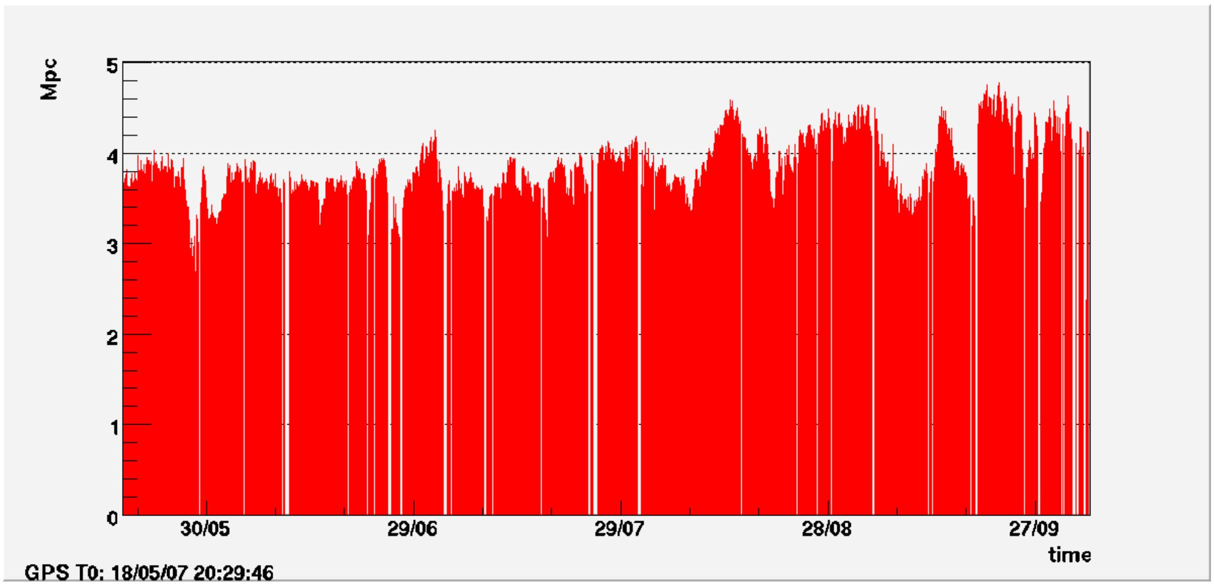

Figure 10 Time trend of the Virgo average oriented NS-NS inspiral range during VSR1 (the ordinate is expressed in Mpc).

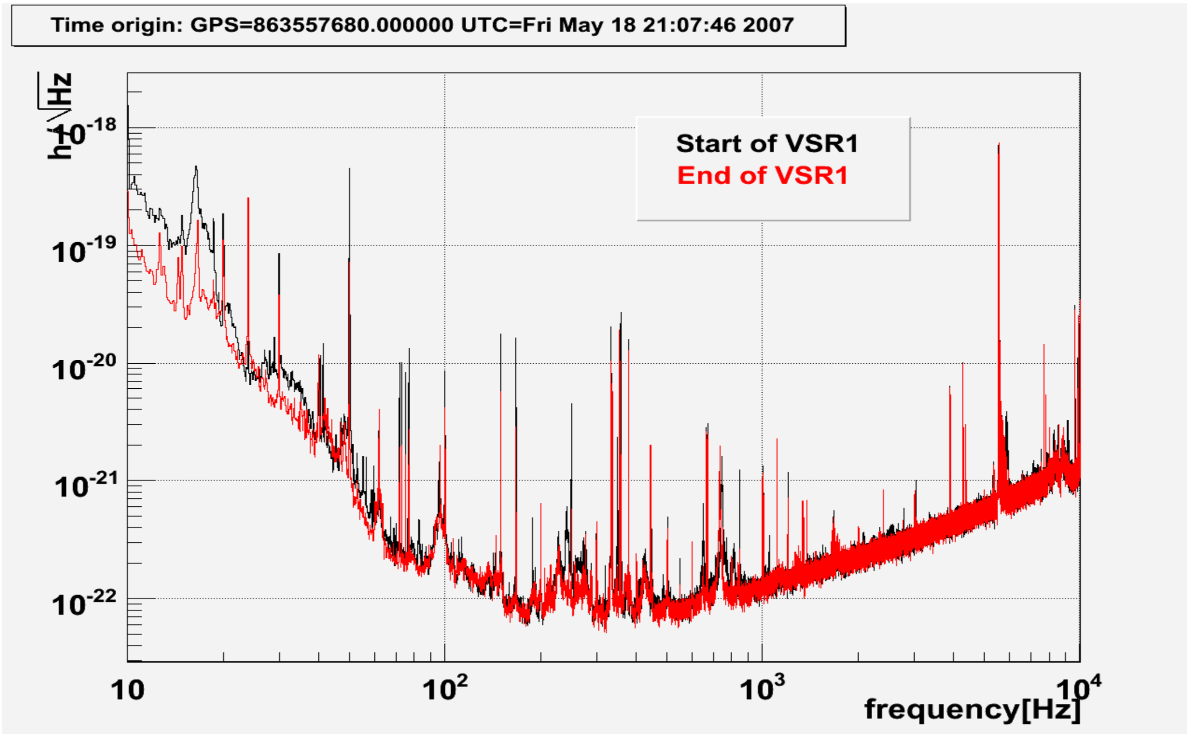

Figure 11 Comparison between the measured Virgo strain sensitivities at the beginning (black) and at the end (red) of VSR1.

2.5 VSR1–S5 Joint detection Duty Cycle

The triple coincidence duty cycle among the three longest baseline detectors Hanford H1 Livingston L1 and Virgo has been of about 58% (see Figure 12). The quadruple coincidence duty cycle including Hanford H2 has been of about 54%, and the quintuple coincidence including GEO600, operative only during night time, has been about 40%.

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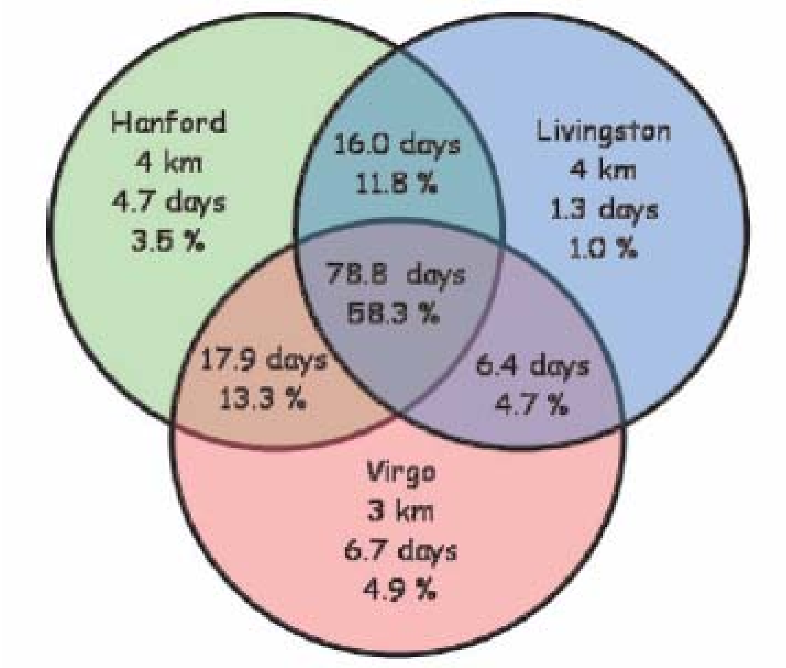

Figure 12 Coincidence duty cycles between Virgo, Ligo-Hanford H1, and Ligo-Livingston

3 Commissioning report

3.1 Introduction

At the time of the last report the VSR1 run was just started. The run ended on the first of October and the commissioning activity restarted then. Small commissioning breaks took place during the run and some improvements could be performed: the unlock rate has been reduced, the stability improved, the control noise reduced and magnetic noise and beam jitter noises have been identified and cured. Long term operation also allowed putting in evidence slow effects such as alignment drifts and the Etalon effect as well as their impact on the sensitivity. These activities are reported here as well as the plans until the shutdown for Virgo+ hardware installations. A comparison of the sensitivity at the start of VSR1 (May 18th) and a week after its end (Oct 9th) is shown in Figure 13.

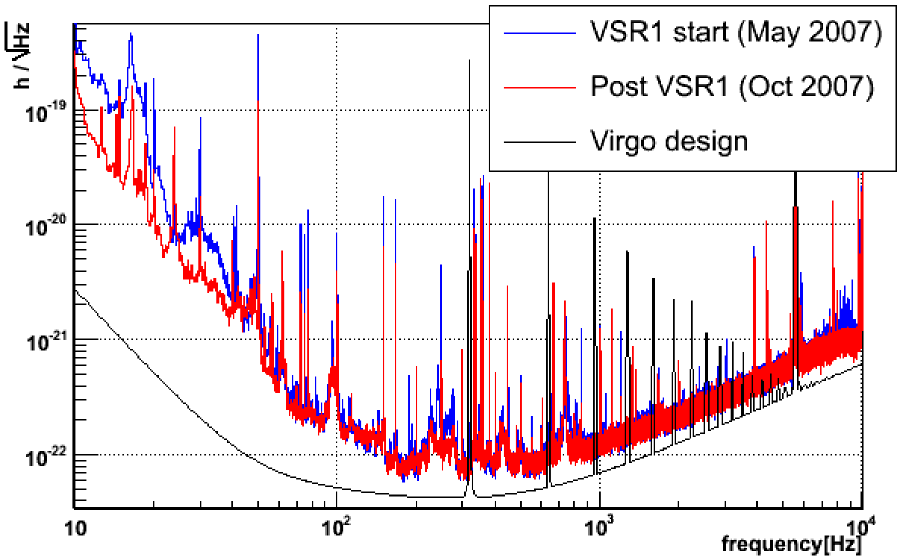

Figure 13 Comparison of the sensitivity at the start of VSR1 (blue) and a week after its end (red). The Virgo design is also shown.

The maintenance periods, dedicated to vacuum and infrastructures activities (4 hours/week), were also used for commissioning activities which didn't need the interferometer locked like investigating or solving technical problems or for magnetic noise investigations. For other commissioning activities there was dedicated timeslots of typically 4 hours each week.

During the first month of the run many unlocks were due to fast unlocks of the injection system. These have completely disappeared after several tuning of the laser lock loop.
Earthquakes were found to be a source of few unlocks per week. A monitoring of suspension signals allowed to detect the arrival of earthquakes and to switch to a more robust control. The final solution has been the implementation of the full global inverted pendulum control.
Another rather large source of unlocks are the crashes of the global control software which could not be understood.

Alignment drifts have been identified at the beginning of the run and a temporary solution has been put in place. The final solution will make use of a centring system compatible with the science mode operation.

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Some filters used for the longitudinal controls and the angular controls have been improved in order to reintroduce less noise. This results in an improvement of the sensitivity below 50 Hz seen on Figure 13. Some studies have also been done on longitudinal control strategy.

Several sources of input beam jitter have been eliminated resulting in the disappearance of noise structures from 200Hz to 900Hz as well as a reduction of the trigger rate in the data analysis pipelines. The noise of the mirror actuators has been reduced and does not limit anymore the sensitivity. The magnetic noise has also been reduced.

After the run, during two weeks, a campaign of measurements has been performed in order to characterise the actuator chain, the optical matrix of the interferometer and the introduction of noise by the suspension controls. These measurements are now used to improve the controls.
The optical calibrators have also been completed and tested. Environmental noise investigations have also been performed.

The commissioning of Virgo will go on until the beginning of the Virgo+ shutdown (May 2008) and will be focused on improvements useful for Virgo+ like the thermal compensation, the reduction of environmental noises and control noises

3.2 Detector operation, electronics and software

3.2.1 Detector operation

Recent activities

During the last period, the Detector Operation activities were mainly devoted to support the carrying out of the Scientific run VSR1 and to continue the definition and development of the web-based monitoring tools (interlaced with the Electronic and Software).

- ***Operator service*:** The operator is in charge to perform the routine operations as well as the basic troubleshooting (recovery for software crashes, earthquakes, etc.) and, in case of the more complex problem, to contact the proper on-call person and to assist him remotely when required. During VSR1 one operator was present in Control Room during each shift (3 shifts/day, 8 hours each shift). During commissioning period, there are 2 shifts/day (week-end not included).
- ***Automation:*** The efficient automation so far implemented is a key element of the good duty cycle reached during VSR1 and to the commissioning activity. Further development has been done during the run for the integration of an earthquake guardian (see 1.3.4) and of the hardware injections.
- ***Training/ Procedures*:** The procedures to operate the ITF are regularly collected and maintained, in collaboration with the relevant sub-system experts and a few Operators. A training session for the Scientists on shift during VSR1 has also been organized.
- ***Monitoring tools*:** for better support and troubleshoot in Control room, a few monitoring tools have been developed and deployed. It is also worth mentioning that these web tools are particularly useful also for persons outside the control room (on-call persons included), to know details on the ITF status. They are web-based and are accessible from the Detector Operation web page (http://wwwcascina.virgo.infn.it/DetectorOperations/index.htm). This web page contains also dynamic frames, displaying the automation status, the ITF step and mode (Science, Maintenance, Adjusting, etc). In particular, the Detector Monitoring tool, essential for the detector operation, displays on a centralized interface the state of all the Virgo sub-systems. Further improvements consisted in adding the archiving/search functionality. Another useful web tool is the “ITF Events Monitor” that displays and

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stores the current actions on the ITF. The new version is database-driven, and the query functionality and more kind of events displaying have been recently implemented.

Planned activities until the Virgo+ shutdown
- Start an upgrade of the automation focused on the improvement of its robustness and on the implementation of the diagnosis and recovery of crashes or software failures.
- Complete the new version of the ITF Events Monitor, aimed to display and store further information, like the ITF mode, the event duration, manually inserted notes, links to other pages, etc.

3.2.2 Electronic and software

Most of the software have been frozen at the beginning of the run and only few small modifications were performed during the run (some servers have been running non-stop for the whole run). The Data Analysis software distribution has been made available on the web and installed in the Bologna and Lyon Computing Centers.

The main problem was due to the crashes of the Global Control software, a cause of a large fraction of ITF unlocks with long recovery time. These crashes have not been understood. The other problem was a loss of frames during data writing on disks which has been diagnosed and solved in the middle of the run.

Several improvements of the injection electronics have also been performed during the run (see 3.3.3).

Current developments and plans:
The phase lock of the two modulation frequencies (6 and 8 MHz) has been put in place after the run. It is now possible to increase the modulation index of the 8 MHz without any trouble.
A dedicated server for the laser and Faraday isolation remote tuning is ready and has been tested on the Virgo Test Facility and the optical lab and is ready to be installed.
After several problems with the air conditioning dedicated servers reading data from the air conditioning system has been put in operation.
A new version of the DSP server will be put in operation to fully support the latest Global Inverted Pendulum Control features (see 3.3.4 below).

The major effort is now put into the preparation for the updates associated to the Virgo+ Control and DAQ electronics and the porting of the associated software (Global control, Photodiodes Readout, etc.).

3.3 Interferometer control and characterisation

3.3.1 Injection system

VSR1 gave the opportunity of a better characterisation of the injection system and several improvements could be done during the run. Except those few fixes which are reported here the behaviour of the injection system was satisfactory during the run.

Injection unlocks
The injection has been responsible for one of the major part of interferometer unlocks, mainly due to the so-called injection "fast unlocks". The "fast unlocks" of the injection system have existed for a long time and their rate increased at the beginning of the run. After several

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investigations these have been cured by tuning the injection locking laser loop to prevent oscillations. Since then (early July) no fast unlocks have been observed.
Other unlocks were due to a 60Hz oscillation arising on the master laser piezo and the electro-optic (EO) correction used for the laser frequency stabilization. This oscillation produced a saturation of the EO correction and, as a consequence, an unlock of the interferometer. The electronic board has been slightly modified in order to no more saturate the EO element. These events are not observed any more since then.

Beam jitter and input mode cleaner length noise
Several sources of beam jitter have also been discovered and solved during the run. These were sources of non stationary noise in the dark fringe from 80 Hz to 1 kHz.

First some glitches visible on the gravitational wave signal have been identified as coming from one of the Beam Monitoring System (BMS) piezo-actuators. The faulty piezo has been replaced and all the false events have disappeared (see 3.4.2 below for more details).

Then some investigations have also been carried out in order to understand the so-called "Mystery Noise", responsible for non stationary structures from 80 Hz to 1 kHz in the dark fringe. This noise was visible in the suspended injection bench (SIB) alignment error signals and as frequency noise and was suspected to arise from beam jitter or diffused light at the level of the suspended injection bench. It was shown that it was possible to excite these structures by shaking the suspended injection bench with the ground coils. The needed noise level was too high to think that this noise could be due to noise induced by the ground coils or through the suspension.

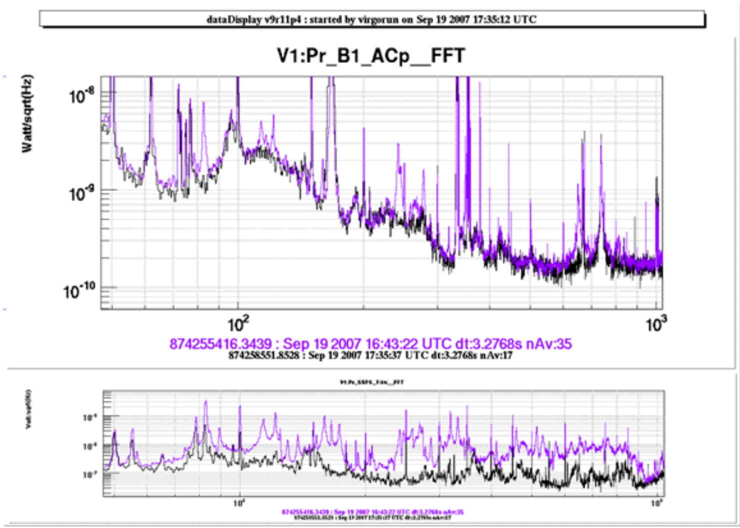

Figure 14 Upper plot: Spectrum of the dark fringe before (purple) and after (black) the piezo driver modification ; Lower plot: Spectrum of the SSFS error signal before (purple) and after (black) the piezo driver modification.

The investigations focussed therefore on the actuators located on the SIB (piezo-actuators, picomotors and translation stages) that are always connected (since a constant voltage has to be applied). It was discovered that the piezo-actuators (used for the reference cavity alignment) were responsible for this noise. The noisy driver of the piezo actuators was inducing a motion of the SIB and therefore beam jitter noise and IMC phase noise. Some low-pass filters (frequency cut-off < 1 Hz) have been put on each piezo driving cable to lower the

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driver noise. Figure 14 shows the improvement on the dark fringe (upper plot) as well as the large improvement of the frequency stabilisation error signal.

Post VSR1 activities
Strange loss of power were observed during VSR1 between the slave laser and the under-vacuum suspended injection bench (SIB) as well as a large dependence of the laser bench output power with respect to the temperature. The alignment of the laser bench (slave laser + the laser beam path after the slave laser) has been checked afterwards and improved. It was found that the second modulator (EOM) was reflecting almost 10% of the incident beam this could explain the power variations observed during VSR1. After its cleaning a good situation was restored. A spare is ready to replace this EOM if necessary.

The SIB and IMC automatic alignment control filters will be improved especially to lower the noise introduced by these loops during bad weather conditions.
The Beam Monitoring System (BMS) piezos and mounting system will be changed to reduce the remaining contributions of BMS resonances in the dark fringe.
The laser power remote tuning system is ready to be installed when needed.

3.3.2 Angular control

The figure below gives an overview of the alignment configuration used during the last science run. Eight quadrant diodes (QD) look at the beams coming out of the interferometer, but out of the four terminal QDs only one is used for interferometer alignment due to the poor quality of their signals. Instead, the beam position on the terminal bench cameras is used for input mirror drift control (beam steering into the arm cavities). One quadrant diode is demodulated at a second modulation frequency (8 MHz) for obtaining an error signal for the common end mirror motion.

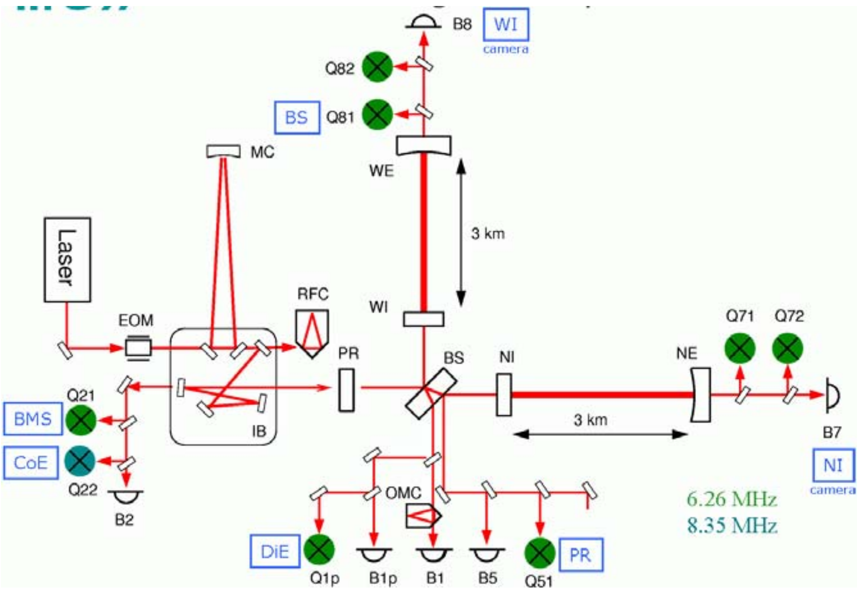

Figure 15 Virgo alignment layout. The blue rectangles show the degrees of freedom controlled with each quadrant diode (green circles) NI/WI = North/West input mirrors;

BS = beam splitter; PR = Power recycling mirror; BMS = input beam steering system; CoE,DiE = Common/Differential End mirror motion. NI/WI are controlled with camera position signals.

Status during the run
Due to the improvements in overall low frequency noise, the alignment noise is now close to limiting the sensitivity in the 10…20 Hz region (see figure), especially the pitch motion of the beam splitter, which has still a contribution from a local control error signal.

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There were a few alignment problems during the run, which could however be quickly fixed: there were large beam centring fluctuations on a quadrant of the West end bench (Q81), which were transmitted to the beam splitter alignment and caused horizon fluctuations. For not disturbing too much the run configuration, we renounced on the possibility of installing a fast beam centring system lent by Geo, and patched the BS error signal by compensating for the quadrant miscentring in the sensing matrix; this solved the problem until the end of the run. Another problem, also on the West end bench, was long term (months) beam drift, which, taking into account the magnification of the alignment telescopes, caused a 10 mm rise of the beam on the quadrant diodes. This slow drift was probably due to subsidence of the building; it was compensated by realigning the optics on the bench.

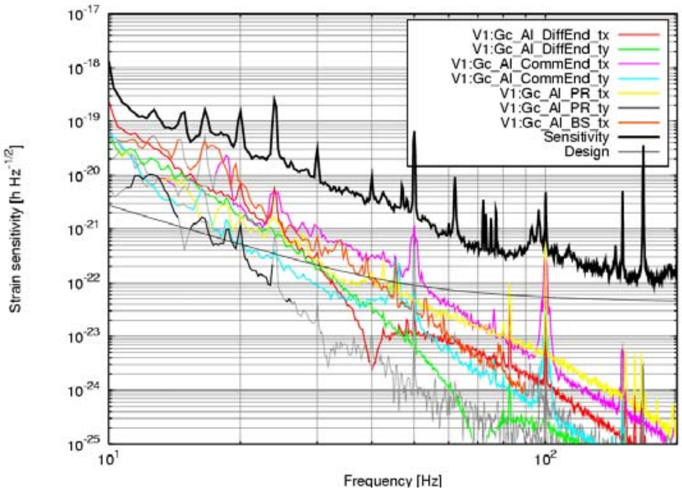

Figure 16 Alignment noise budget. Alignment noise is close to limiting the sensitivity below 20 Hz.

Alignment system plans up to Virgo+

In the first commissioning phase, several relatively non-invasive changes are foreseen. Two more quadrant diodes will be installed in the dark fringe and beam splitter pick-off beams in order to obtain additional alignment error signals; this will help in our effort to improve the alignment control scheme by eliminating the remaining local control contributions in the (slow) drift control alignment loops (BS tx, NI, WI, input beam). The modulation depth of the secondary modulation frequency (8 MHz) will be increased in order to improve the common end mirror alignment noise. Improved filters with higher low frequency gain will be installed in the injection bench autoalignment system for reducing input beam jitter and improving the stationarity of interferometer parameters.

More invasive changes are foreseen later on. The quality of the alignment signals on the end benches will be improved by substituting the beam reduction telescopes; this will reduce the spherical aberrations and the extreme touchiness of the second telescope lens, and will be the occasion to set the quadrant diodes in a clean near/far field configuration for obtaining more decoupled error signals. At the same occasion we will install on all benches fast galvanometer scanner systems for centering the beam on the quadrant diodes; this will avoid problems like the one mentioned above with the miscentering of Q81. The higher quality of the error signals should make it possible to use quadrant diode signals instead of noisy camera signals for beam steering control (acting on the input mirrors).
The change of the main modulation frequency, presently under discussion for Virgo+, would reduce the RF signal available for alignment on the end benches; on the other hand, one of the main concerns for the alignment commissioning before VSR1 was the extreme sensitivity of the control system during the thermal transient after lock acquisition. An implementation of

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the new modulation frequency, together with the thermal compensation system, would help making the alignment system more resistant in the first steps of lock acquisition.

Another important change for Virgo+ is the change of the quadrant diode front-end electronics. The main desired improvement is a noise reduction by a factor 3, putting constraints on the preamplifier noise at low powers (dark fringe), and the maximum light power capacity in the shot noise limited zone. Whether all requirements can be met is yet to be verified, but we can probably take advantage of the higher light power available in Virgo+ for reducing the noise on some beams.

3.3.3 Longitudinal control

The performances of the longitudinal sensing and control system during the science run have been quite good. Indeed the lock acquisition sequence worked almost all the times, with exceptions during periods of quite bad environmental conditions and some times after the maintenance period, due to heavy interventions that changed the temperature inside the laser laboratory. The stability of the locking system has also been remarkable, making possible to maintain the detector in its working condition with stable sensitivity for very long periods (see VSR1 statistics report). Only a small fraction of the un-locks has been caused by instabilities in the longitudinal controls and most of these were triggered by external conditions (high micro-seismic motion for example).

Performances of the slow gain servo loops

The sensing matrix (which is used to reconstruct suitable error signals from the photo-diode outputs) is composed by three diagonal terms that are used to reconstruct arms differential (DARM) error signal from B1_ACp, the power recycling (PRCL) error signal from B2_ACp (mixed at low frequency with the signal at 3 times the modulation frequency, B2_3f_ACp) and the Michelson (MICH) error signal from B5_ACq. There is moreover a off-diagonal term (called crossMP) used to subtract the contribution of PRCL noise from the MICH error signal, combining B2_ACp and B5_ACq. All the values of this matrix proved to be not constant in time. Therefore slow servo systems have been set up to measure the optimal values of these parameters and to change them accordingly. The diagonal terms are servoed in order to maintain the unitary gain frequency of the three longitudinal loops at the desired values (100 Hz for DARM, 40 Hz for PRCL and 15 Hz for MICH). The crossMP parameter is also changed slowly to minimize the cross-talking of PRCL and MICH loops.

Moreover, as explained in the previous report, two noise subtraction techniques have been implemented to reduce the contribution of MICH and PRCL controls to the detector noise.
The MICH noise subtraction takes the correction applied to the MICH degree of freedom, process it with a suitable filter and send it to the differential mode of the end mirrors. The shape of the filter has proved to be very constant during all the run, while its overall gain changes significantly. Another slow servo system has been implemented to cope with this variation. The noise cancellation obtained with this technique is better than a factor 100 at all frequencies.
A similar technique is used also for the PRCL noise, with a frequency independent subtraction and a gain controlled by yet another slow servo. The performances of this subtraction are not as good as the other one and indeed the contribution of PRCL noise to the sensitivity have sometimes been not negligible (see 3.3.5).

Since the beginning of the run, the good balancing of the sidebands at the dark port has proved to be a crucial element to acquire and maintain the lock of the interferometer. This balancing was known to be strongly dependent on the offsets added to the error signals

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obtained from B5_ACq and B2_3f_ACp. Indeed another slow servo loop has been implemented to maintain the sidebands balanced acting on B2_3f_ACp offset. This strategy worked quite well during the first months, even if it proved to be the origin of troubles when the offset became too large. Moreover it induced variations of the recycling gain, since this offset resulted in both a MICH and PRCL displacement. Therefore a different strategy has been studied and actuated. Now the offset is added on both B2_3f_ACp and B5_ACq, with slightly better performances like some noise reduction below 50 Hz.

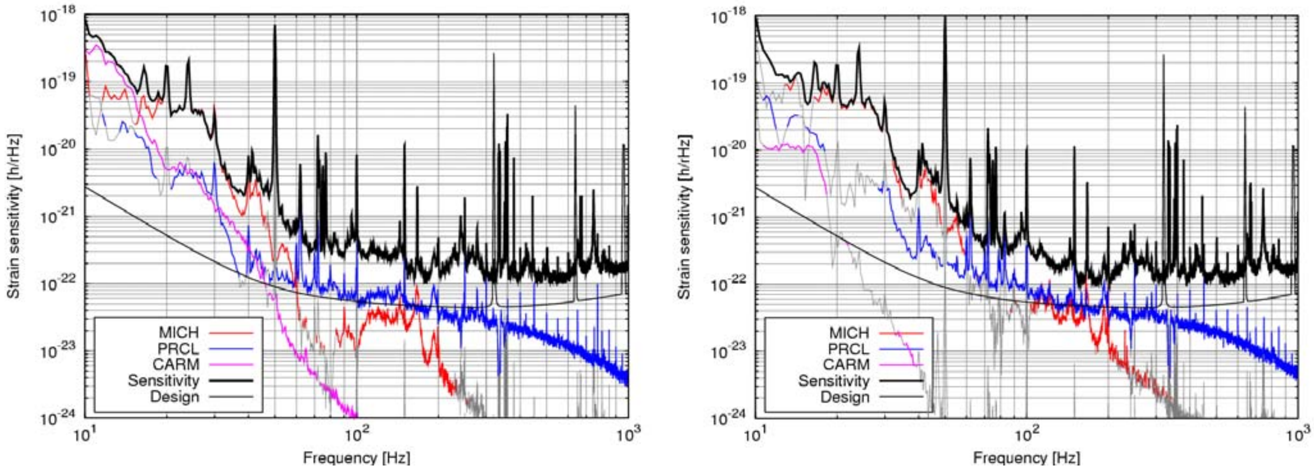

Figure 17 Comparison of the longitudinal noise budget measured at the beginning and at the end of the run: the CARM control filter has been modified as well as the strategy for the sidebands balancing. The noise re-introduced by the CARM loop is plotted in pink. The contribution has been reduced by a large factor over all the bandwidth and it is even below the design sensitivity above 20 Hz.

Reduction of control noise

After several other improvements, at the beginning of the run it became clear that one of the limiting sources of noise at low frequencies was coming from the CARM control loop, which is the system that maintain the end mirror common mode locked on the reference cavity, with a bandwidth of the order of 1 Hz. The coupling of this noise has been reduced in two steps. First a better balancing of the actuation of the common mode has been obtained, changing the corresponding relative gain of the NE and WE mirrors. Moreover an improved version of the control filter has been implemented, allowing a strong reduction of the noise above roughly 9 Hz. See Figure 17 for a comparison of the situation before and after the change.

Future plans

The activities planned for the first period of time after the end of VSR1 are mainly concerned with locking characterization, with the goal of gaining a better understanding of the detector response to longitudinal motion and of improving the control, both in terms of stability and noise performances.
A measurement of the longitudinal optical matrix of the interferometer (which is the set of all transfer functions from mirror motions to photo-diode outputs) has been performed. This will allow a better reconstruction of the error signal used now for the control.
Moreover the relative gain of the BS and PR actuators have been measured. This will allow a better diagonalization of the driving of MICH and PRCL degrees of freedom.

Finally the use of signals coming from the demodulation at 8 MHz of the B2 photodiode, after phase-locking the 6 and 8 MHz modulations and increasing the 8 MHz modulation index, will be investigated. This might give a better signal to control the MICH and PRCL degree of

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freedom, in place of Pr_B2_ACp which is right now the believed source of the low frequency noise in the longitudinal error signals.

The installation and commissioning of the thermal compensation system will have a major impact on the locking activity. A first step will involve the study of the behaviour of the corresponding error signal during lock acquisition and mainly the thermal transient, with the goal of developing the strategy to use it to actively compensate the thermal effect in the input mirrors. If effective this will imply the modification of the locking strategy from the moment when the dark fringe is reached up to the science mode operations.

3.3.4 Mirror suspension control

Several preparatory improvements had been implemented before VSR1. These implementations were meant to be flexible, namely they were tuneable with negligible impact on the ITF sensitivity performance, and aimed to enhance operation robustness and, hence, increased duty cycle, preventing external disturbance. Remarkably, VSR1 provided a unique opportunity to study the detector under stable and standardized conditions. Indeed the short commissioning breaks were exploited to perform relevant improvements described below.

At the beginning of VSR1 the essentials of mirror suspension controls configuration were the following (see previous report for details):

- The Global Inverted Pendulum Control (GIPC) for the terminal suspensions: the ITF longitudinal locking signal is used instead of the local position sensor (Lvdt) and combined with the accelerometers.
- A tuneable combination of position and accelerometer signals for the central area suspension control to face different environmental conditions.
- Quadratic compensation of the angular recoil on both Marionette and Superattenuator chain (F7);
- The reallocation of the force to the Marionette on input and end mirrors to reduce the dynamic of the signal on the reference mass;

All these items were meant to improve accelerometer disturbance rejection during windy days and to minimize the micro-seismic noise re-injection through position sensors (LVDT). For instance, using GIPC means to use a cleaner signal, derived from global ITF control thus allowing an increase of the crossover frequency (70 mHz) between the accelerometers and the position sensors (Lvdt).

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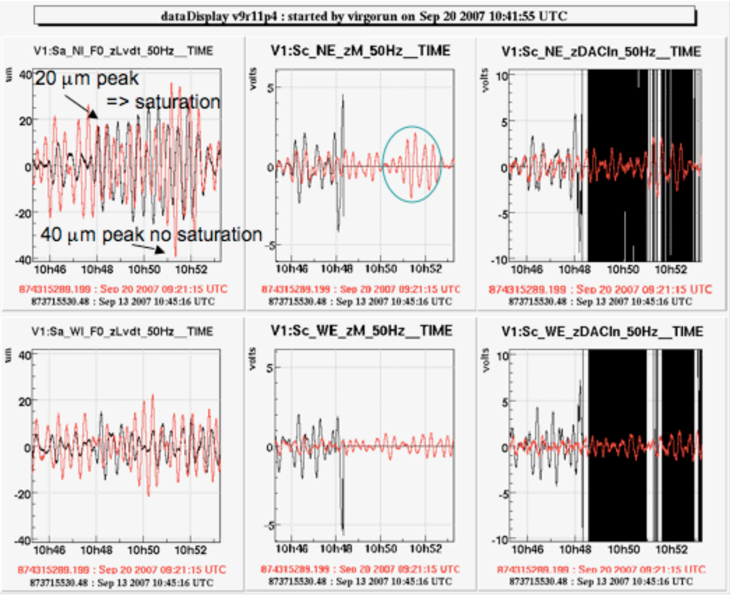

Figure 18 6.8 M earthquake in Indonesia few days after full GIPC implementation. A previous event (smaller, Sept 12) unlocked the ITF due to actuator saturation. Instead, thanks to the new GIPC setup the system stands and the actuator dynamics more than doubled The biggest correction applied to the marionette (green) corresponds to 7 µm.

Main improvements performed during VSR1:
Reduction of the angular control noise in the dark fringe

1) A tuning of the BS angular Local Control was needed in order to prevent the presence of low frequency non-stationarities observed in the sensitivity (~100 mHz).
2) The centring of the mirrors with respect to the beam has been improved. This improved the sensitivity in the range 10-15 Hz.

Differential control of the suspension top stages:

1) Earthquake guardian: The duty cycle of Virgo was affected by re-lock recovery times rather long after unlocks due to earthquakes. At VSR1 beginning far earthquake events from Mag 5.6-5.8 used to cause operation unlocks. The shake due to a far earthquake waves is quite coherent over a 3-km baseline. The GIPC strategy, applied at end towers to make top-stage control more robust in windy conditions, was unstable in case of coherent disturbance, over the FP arm like in case of earthquake. This is due to the fact that GIPC is a combination of a differential position signal (cavity length variation, derived from the locking force) with a local top-stage acceleration. A Guardian (EQG) was therefore put in place in order to disable GIPC in case of earthquake. This was an automated process based upon the behavior of suspension signals and environmental vetoes. The EQG allowed to reduce saturation occurrence causing unlocks to a rate comparable with other main unlock sources (~1/week).
2) Improved GIPC and EQG removal: Finally we managed to send through optical links the signal of input mirror top-stage accelerometers to the end towers allowing hence the true reconstruction of end tower top stage with respect to the input tower ones. Having the full reconstruction (position and acceleration instead of position only) the GIPC was no longer unstable during earthquakes as illustrated in Figure 18. The earthquake guardian was no more needed.
3) Differential control of the central suspensions: In most cases of earthquakes the locking force used to saturate Power Recycling mirror actuators. Hence it was decided refer PR top stage motion to the North-Input mirror. This configuration is called µSeism-Free-

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Reconstruction (µSFR) meaning that since µSeismic disturbance (sea), is common among LVDT suspension top-stages in the central area, its contribution to the differential sensor reconstructed is cancelled and allows to increase LVDT/ACC cross-over frequency to avoid low frequency malfunctioning of accelerometers causing actuator saturation. Following the same idea the top-stage signals of the input towers have been linked to the BS allowing the µSeism Free Reconstruction also for BS.

The suspension control strategy at the end of VSR1 is illustrated in Figure 20 and its performances in Figure 19.

Foreseen improvements after VSR1

Noise sources involved in mirrror suspension control did not limit the sensitivity performance during VSR1. However, the system showed to be still sensitive to environmental noise especially during days with high µseism activity (sea). In such cases drops in NSNS horizon up to 30% were observed. Thus a campaign of system characterization has been performed by means of One-By-One injections at suspension top-stages during stable and environmentally quiet performance. The aim of these measurements is to assess the major disturbance entry–point and to clarify the mechanism of coupling with the dark fringe signal.

The optimization of short suspensions (IB,MC,OB) is also planned. It implies the reparation of HW components (MC,Accelerometer), inverted pendulum tuning (MC) and vertical damping implementation.

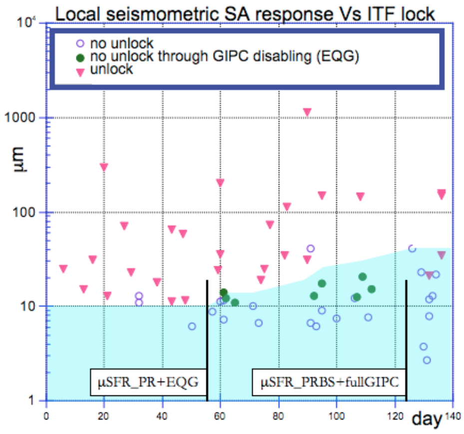

Figure 19 ITF unlocks versus the amplitude of local disturbance: in the mid July Earthquake Guardian and µSFR for PR were implemented thus saturation unlocks in case of earthquakes was reduced by 40 %. Finally µSFR and GIPC were fully implemented with a further overall robustness improvement

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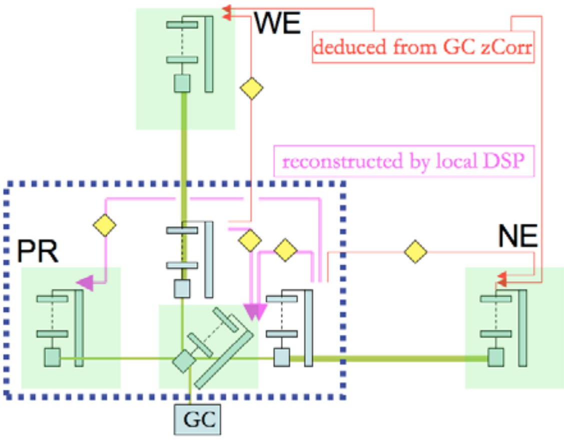

Figure 20 Top-stage control strategy adopted in the final VSR1 phases. Diamonds show interconnections between suspension top-stages enabled during the run: a differential error signal network referred to input mirror has been built..

3.3.5 Optical characterisation

The Optical characterization of interferometer has been dedicated to various tasks. Among them the measurement of the etalon effect and its importance on interferometer stability and sensitivity; a better characterization of sidebands behavior; a design of the optical system for generating error signal for the thermal compensation (TCS), which will be implemented at the beginning of 2008.

It was expected that the finesse of the FP cavities changes with the temperature of the input mirrors (etalon effect): this is due to the fact that the thickness of the mirrors changes with temperature; this leads to variation of their effective reflectivity due to the non perfect AR coating of the second face. The etalon effect, and its temperature dependence, has been observed directly through the variation of the finesse of the cavities. The measurement of the temperature of the input mirrors, with the resonant mode technique, has made it possible to link the observed finesse amplitude and periodicity (corresponding to half wave equivalent path) to the reflection R1 of anti-reflected coated surface and the refraction index derivative dn/dT, see Figure 21. The measured values are R1 = 300 ppm which is twice the value measured in Lyon before installation and dn/dT = $0.80\times10^{-5}K^{-1}$ which is near the expected value of about $1\times10^{-5}K^{-1}$. The observed finesse asymmetry is ±4%.

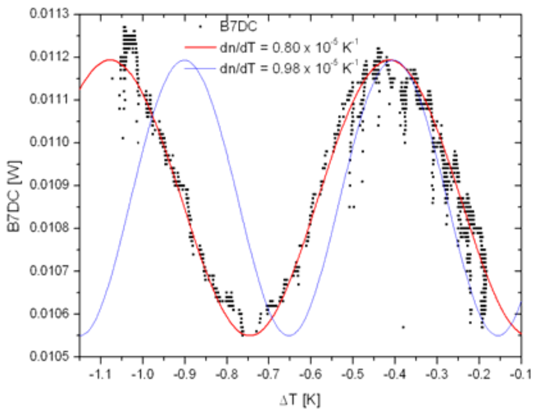

Figure 21 Power transmitted by North arm as a function of the input mirror temperature. The colored curve show the prediction for two different refraction index

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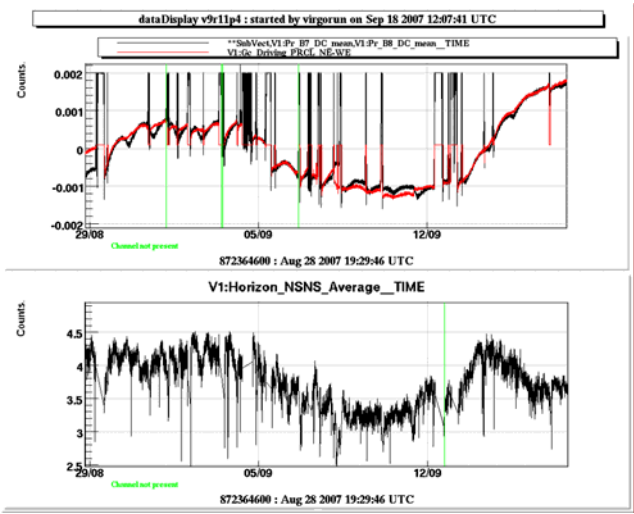

Figure 22 Coupling of the PR longitudinal control noise to the dark fringe (top, red curve) compared to the (rescaled) finesse asymmetry (black): the horizon (bottom) is reduced when the absolute value of the coupling is large.

It was also observed that the coupling of the PRCL (see 3.3.3) longitudinal control noise to the dark fringe is proportional to the finesse asymmetry (like for frequency noise). Therefore the increase of finesse asymmetry produces a decrease of the horizon, as shown in Figure 22. At the moment the use of an external lamp on WI and NI (of few watts) has demonstrated to be sufficient to reduce the finesse asymmetry and stabilize the horizon. This control has to be characterized for Virgo+.

A second activity has been dedicated to better understanding the sidebands behavior in the interferometer. The parallel work of simulations with DarkF and phase camera measurement has shown a substantial agreement. This result is considered promising especially in view of thermal compensation activity, because it will lead to a more confident measurement of TCS actuators. Finally a simple scheme for error signal extraction for TCS has been designed, essentially consisting in a pin-hole mirror at 45 degrees. The mirror splits the inner and external parts of the beam sending them to two photodiodes. This will be installed end 2007.

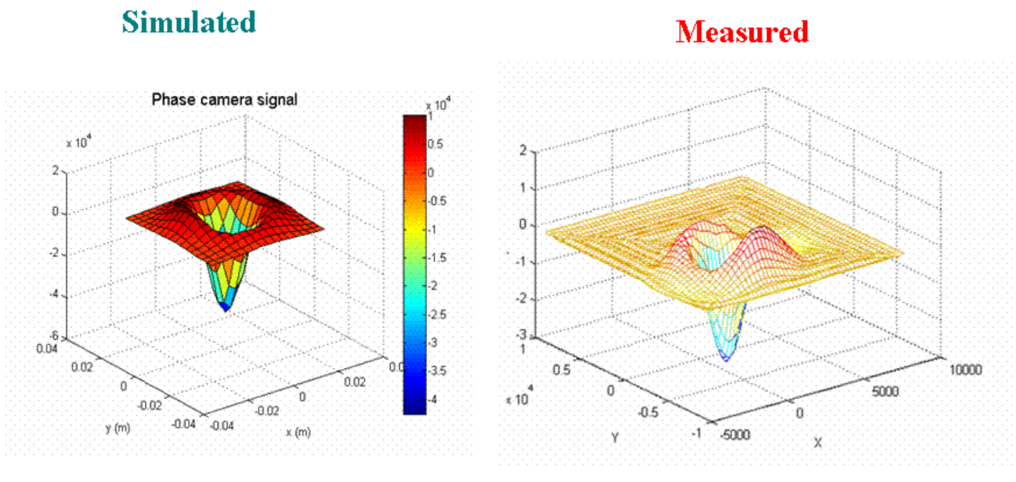

Figure 23 simulated and measured sidebands wavefronts in presence of mirror thermal deformations

3.4 Noise hunting

3.4.1 Magnetic noise

Sources of magnetic noise have been searched for inside all the ovens (starting with the input mirrors since their magnets are mounted with the wrong polarity) with a Hall probe. All the dominant sources have been removed. In particular the fan of the illuminators used for the local controls were known to produce strong magnetic field and have been switched OFF since these fans are not mandatory. Other power supplies have been put further away from the mirrors. These sources were responsible for lines around 50 Hz and 100 Hz. Figure 1 shows the dark fringe around 40 Hz at the beginning of the run and at the end as well as the magnetic noise measured on the fans: the magnetic lines of the fans were clearly seen in the dark fringe and have now disappeared. We believe that the main sources of magnetic noise have been eliminated but this work will nevertheless go on.

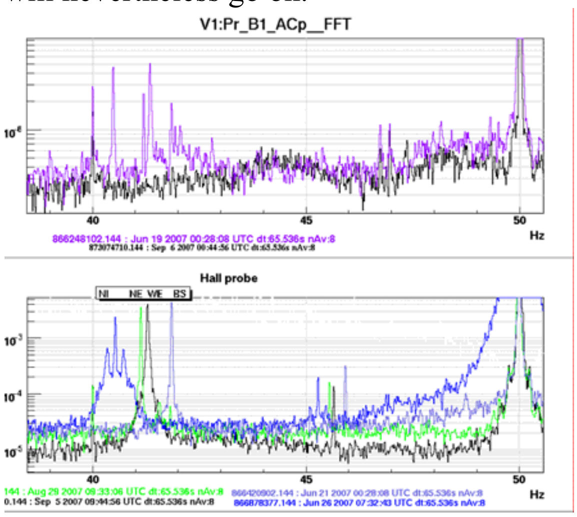

Figure 24 Reduction of magnetic noise (top dark fringe, bottom: hall probe at several locations)

3.4.2 Beam jitter and IMC length noise

Several sources of beam jitter have been identified and solved during the run:

1- Beam monitoring system piezos:

Some events found by the data analysis pipelines were coincident with glitches in the signals of beam monitoring system (BMS) used to align the beam on the input mode cleaner. It was found that these glitches were due to a malfunctioning of the piezo of one of the BMS mirrors (see 1.3.1). This piezo has been replaced and these glitches disappeared as can be seen in Figure 25 where events found by a burst analysis are shown (red and green points around 150 Hz).

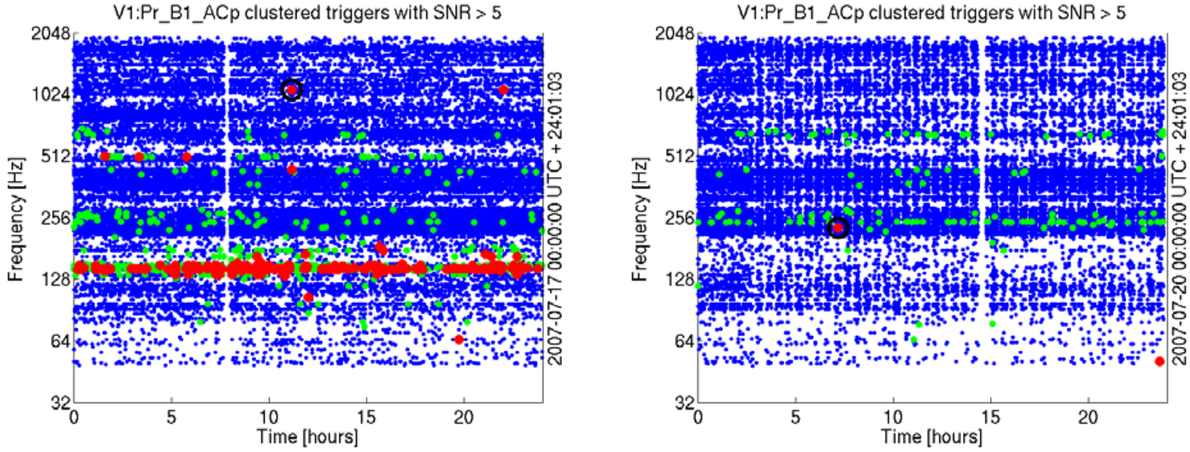

Figure 25 Online Bursts search : Situation before BMS piezo substitution (left plot), Situation after BMS piezo substitution (right plot).

Several mechanical resonances of the BMS piezos and mounts have been identified between 150 and 400 Hz and these are also seen in the dark fringe. Better piezos are been tested and will be installed soon.

2- Suspended input bench piezos:
The so called mystery noise structures (from 80 Hz to 1 kHz) were highly non stationary and their coupling to the dark fringe was clearly dependant on the ITF alignment. This noise was present on the suspended injection bench (SIB) alignment error signals and the frequency noise while it wasn't observed on the external injection bench. The source was then looked for into the SIB tower (noise due to the tower input window or beam jitter on the SIB). After some investigations if was found (see 3.3.1) that piezos actuators, even if not located on the path of the mean beam, were shaking the whole bench, inducing beam jitter and IMC length noise. These noise structures have completely disappeared.
The pico-motors located on the suspended input and the output benches have also been disconnected to make sure these did not excite any component on these benches.

3.4.3 Environmental noise

After the removal of structures due to input beam jitter (see 3.4.2) the analysis of the remaining noise is slightly easier. Most of the structures from ~100Hz to few kHz are clearly related to acoustic/seismic noise in the central area. Tapping tests have shown that the most sensitive part of the vacuum enclosure is the Brewster link located before the detection tower. The largest coherence between the dark fringe and acoustic/seismic sensors is found with the accelerometer located on the Brewster (see Figure 26). This noise could be due to light retro-diffused by the detection bench on the Brewster or to phase noise induced by the motion of the Brewster window itself. It is planned to reduce the light retro-diffused by the bench towards the Brewster by placing better diaphragms between these two elements and more baffles inside the detection tower. The removal of the Brewster window is also under study. The main worry is cleanliness issues since the detection tower vacuum is polluted by elements such as pico-motors. A cryogenic trap is under study (see Detector report) and should be installed early next year.
Sources of diffused light are also looked for on the external benches.

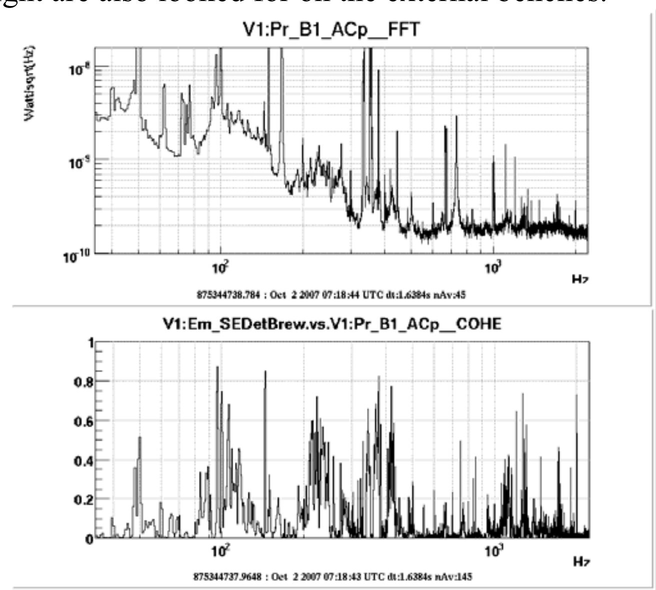

Figure 26 Dark fringe spectrum and its coherence with the accelerometer located on the Brewster link

3.5 Post-VSR1 noise budget and foreseen improvements

The Figure below shows the noise budget few weeks after the end of VSR1: 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 un-modelled noises are the environmental noises which are mainly observed as the structures above the pink curve between 50Hz and 1 kHz. The lines around 70Hz, 300Hz and 600Hz and calibration lines and violin modes.

3.5.1 Shot noise:

Above 1kHz the sensitivity is mainly shot noise limited. The shot noise is computed using the power measured on the dark fringe and taking into account the measured optical gain. It corresponds, within better than 10%, to the expected shot noise for an input power of 8 W, a recycling gain of 43 and a transmission of the output mode cleaner of 80%. This good agreement shows that the optical gain is well understood.

3.5.2 Modulation 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. In particular some glitches in the dark fringe have been found to be due to glitches in the modulation amplitude. Some investigation and improvements of the modulation electronics are foreseen to lower the modulation noise.

3.5.3 Frequency noise:

The laser frequency noise (dark blue and light blue) is now limited by the shot noise of the error signal (B5 photodiode). It usually sits well below the Virgo design except when the finesse asymmetry (i.e. its coupling to the dark fringe) is too large due to the etalon effect (see 1.3.4). This effect can nevertheless be controlled as discussed in 3.3.4.

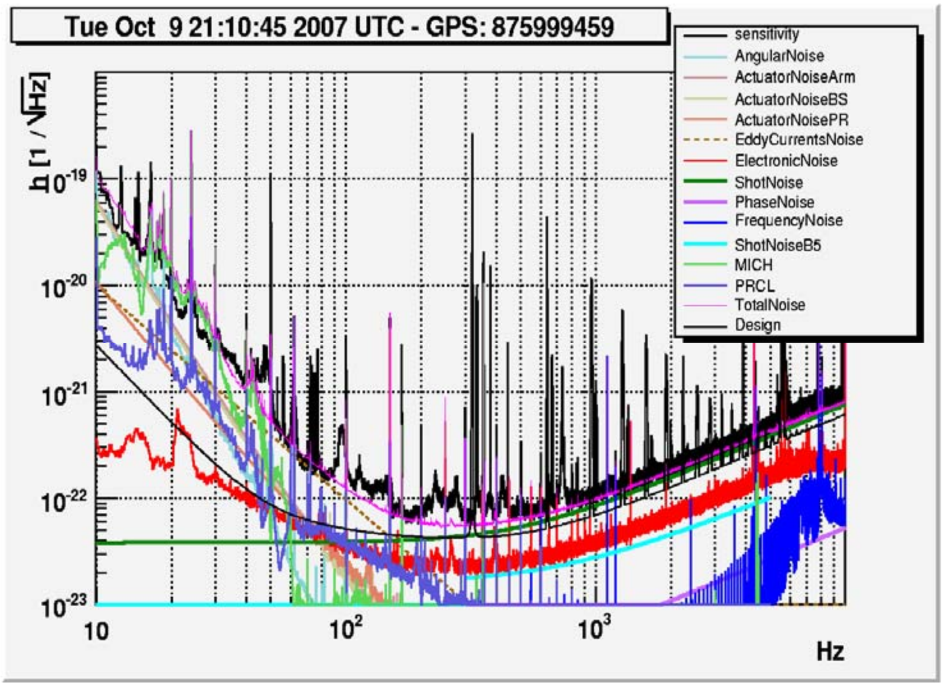

Figure 27 Post-VSR1 noise budget

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3.5.4 *Angular control noises:*

The noise introduced by angular controls limits the present sensitivity only below 20 Hz (see Section 3.3.1). It will nevertheless need to be decreased in the band 10Hz-40Hz 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). The improved telescopes of the end benches should also help to obtain cleaner error signals (see 3.3.2).

3.5.5 *Longitudinal control noise:*

The longitudinal noises are introduced by the control of the PR and BS mirrors.
The PRCL control noise does not limit the present sensitivity thanks to the use of an on-line subtraction. It has been found during the run that its coupling to the dark fringe is proportional to the finesse asymmetry and can therefore be reduced making use of the Etalon effect.
It is only a factor 3 above the design sensitivity below 40 Hz. A cleaner error signal could be provided by the second modulation frequency (8 MHz) or when the thermal effects are reduced). This is under investigation.
The MICH control noise limits the sensitivity below 40 Hz. This noise is due to the PRCL control noise: PRCL motion is sensed by B5 photodiode and then introduced as MICH control noise. Therefore any improvement in the PRCL control noise will lead to a direct reduction of the BS control noise. A better diagonalisation of the sensing and driving matrices is also under study (see 3.3.3).

The electronic noise of the mirror actuators (maroon curves) does not limit any more the sensitivity. Further improvement will be needed in order to reach the Virgo design. This will require the installation of lower noise driving electronics prepared for Virgo+ (see detector report).

3.5.6 *Eddy current noise:*

The noise related to the Eddy currents in the reference mass, shown in Figure 27, is an upper limit, which explains why the total noise is above the measured sensitivity between 60 and 100 Hz. The magnets will be capped when the Eddy current noise will be met.

3.5.7 *Environmental noises – jitter noise:*

Many magnetic lines around 50Hz and 100 Hz have been removed during the run. Some structures from 100 to 1kHz were due to input beam jitter which has also been solved (see 3.4). The remaining structures between 100 Hz and 1kHz are due to environmental noise inside the central area. An hypothesis is diffused light. It was confirmed that the most sensitive piece is the Brewster link. The replacement of the Brewster by a cryogenic trap is in preparation.

3.6 Shot term plans

During the next 6 months (i.e. until the Virgo+ shutdown) the commissioning will focus on improvements which should also be useful for Virgo+:

- The reduction and control of the thermal effects is a key point before increasing the laser power. A cleaning of the mirrors will first be tried (November-December). Then the thermal compensation system will be installed and commissioned (early in 2008). Both actions will imply a re-commissioning of the lock acquisition and a retuning of the longitudinal and angular controls. 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 faster and more robust lock acquisition.

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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 will become more robust and less noisy.

- The environmental noise has to be reduced. An important step will be to remove the Brewster window between the SR and the detection towers. A cryogenic trap will be installed in place of the actual Brewster in order to catch a large fraction of the detection pollution (see Detector report). This should be ready early next year. Before this installation more diffused light mitigation will take place inside the detection tower (see 3.4.3).

- Several actions are planned for the reduction of the longitudinal control noises: the use of the second modulation (at 8 MHz) for the control of PRCL d.o.f and a better diagonalisation of the sensing and driving matrices.

- The work on the suspension control will go on in order to improve the stability in bad weather conditions. It is mainly focused on the IB and MC towers. Better stationarity will also imply to improve the centering of the quadrant diodes during science data taking: galvanometers will be installed for this purpose;

- The angular controls performance should also be improved with the implementation of better filters as well as more quadrant photodiodes. The telescopes of the end benches will be replaced with better ones; this is expected to result in cleaner signals. The new electronics should also allow a reduction of the control noise.

- The new coil drivers, providing more filtering capabilities, will be installed on all the suspensions to further reduce the mirror actuator noise.

- Finally the magnets will be capped when the Eddy current noise is met.

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4 Detector report: Virgo+ preparation

4.1 Preface

The STAC asked to have, for the November 07 meeting, a Virgo+ PEP document. The Virgo+ review panel, appointed by EGO, is asking to have a document that describe the motivation of each upgrade and the eventual effect on the sensitivity of the detector. Since the "Detector" activity has been focused in the last months to the design, production and installation preparation of the upgrades expected in the Virgo+ framework, the usual Detector report should already contain all these information. For all these reasons, the usual report has been modified to attempt to satisfy all the previous requests avoiding a duplication of documentation that should be sent approximately at the same set of persons.

4.2 Introduction: work organization

The Virgo+ phase is born as a natural evolution of the Virgo detector, merging the upgrades needed to fix the components of the machine that behave under-specification and the upgrades of few key components that limit or could limit the sensitivity in particular frequency ranges. Because of this character of continuity with the standard evolution process of the machine, has been decided to keep the usual Virgo organization structure, reserving to the detector coordinator the duty to organize the upgrade process, to monitor the development progresses and to realize the production and installation planning within the strategy framework that should be given by the VSC. The upgrade identification and planning activity is performed in close collaboration with the commissioning coordinator that feedbacks the commissioning progresses in to the Virgo+ development process, contributing to give the right priority to each activity. The monitoring of the progresses of each activity is realized through the detector meetings, at each Virgo week, open to all the collaboration, through planning meetings, focused on each activity and restricted to the detector and commissioning coordinators and to the involved team (usually composed by Virgo people belonging to different labs), and, finally, through the Virgo+ internal review meetings (3rd of April, 2007 and 16th-17th of October, 2007) open to the full collaboration (the last to the STAC and Review panel members) and using activity referees belonging to the Virgo and LSC communities.
The report documentation of the 2nd Virgo+ review is available at the address:
http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/secondVirgoplusReview.html
meanwhile the slides of the talks are available here:
http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/
As already announced to the first review meeting (and at the previous STAC meeting), purpose of this review is the selection of the mature upgrades and the definition of the installation planning, in agreement with the scientific target that should be given by the VSC.

4.3 Upgrade

As already mentioned we can distinguish (with some difficulties, because of the border is never sharp) the upgrades needed to fix current problems and the activities devoted to an improvement of the Virgo sensitivity. Hence, in the last category, we could identify three main families:

- High power lasers (reduction of the shot noise) and related changes
- Monolithic suspensions and mirror replacement for the reduction of the suspension thermal noise
- Electronics upgrade

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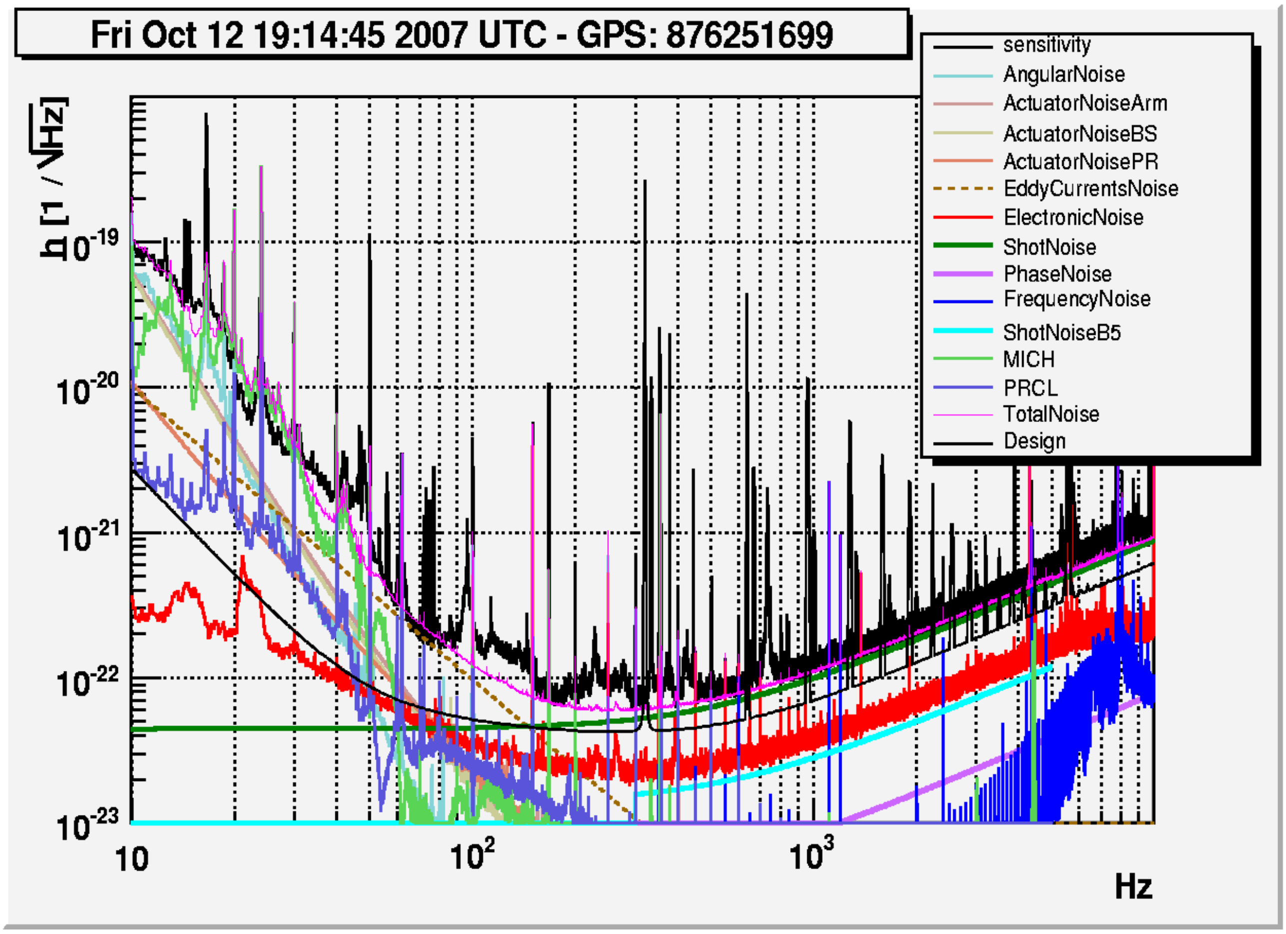

Figure 28 - Virgo VSR1 noise budget

4.4 Current problems fixing

The activities in this family, after the development phase, managed by the detector coordinator, passes under the control of the commissioning coordinator. Currently, in development, we can identify three activities.

4.4.1 Cryogenic trap

The Brewster window and its support link between the SR and DT tower is suspected to be cause of scattering and phase noise in the frequency range 100-800Hz (see un-modelled structures that exceed the total noise projection in Figure 28). Although the previous Brewster has been replaced with a larger aperture one, no major improvement has been achieved and the identification of the noise path is still indeterminate. Nevertheless the removal of that noise structures is fundamental to reach the Virgo sensitivity and to access to the improvements of Virgo+. For this reason an attempt to remove this window is prepared within the commissioning pre-Virgo+ framework Because of the residual contaminants present in the DT tower it is impossible to simply remove that window without contaminating the full ITF. For this reason the link must be replaced with a cryogenic trap that should block the large majority of the contaminants.

Name	Cryogenic trap
Code	Virchrq0102007
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0102007.html
Virgo+ review	*Missing*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Vacuum_Virgo_2ndRev.ppt
Cost (€)[1]	47000 (to be completed if the attempt is successful)
Status	Call for tender issued; offers expected the 6th of November
Responsible	A. Pasqualetti

4.4.2 Thermal compensation

The Virgo sensitivity is limited by thermal effect in the input mirrors. In fact the current laser power, injected in the ISYS, has been limited to 12.5W (of the 17W available) because a larger value causes instabilities (and locking failure) in the ITF due to the sidebands unbalance. With the current injected power the locking procedure is in any case a complicated and long (30 minutes) procedure, because of the thermal transient. The reason of this fact is due mainly to an excess of absorption in the input mirrors (measured through the resonant mode technique), probably due to a contamination of the mirror (it will be verified with a cleaning attempt at the end of November) and of the fact that the sidebands behaviour has not well evaluated during the design phase. As LIGO shown, a Thermal Compensation System (TCS) is a fundamental component of an ITF where a large power is circulating and, hence, it is almost meaningless distinguish if this device is a Virgo o Virgo+ upgrade. The design of the TCS has been completed by the Roma TV group during the Summer and the first orders have been issued in the second half of October. The installation of the TCS system (laser and optical imaging system) is expected in the late February, with at least one month of delay respect to the original plan.. TCS will be completed in June, through the installation of the power stabilization system.

Name	TCS
Code	*Virchrq0112007*
CRE document	*http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0112007.html*
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/Virgo+/2ndReviewDocuments/Virgo+_TCS2f.pdf
Cost (€)	220000
Status	Final design of the major components ready; large fraction of the orders in progress; cost increase monitored through meetings
Responsible	A. Rocchi – V. Fafone

4.4.3 Phase Camera

This project has been attributed to the Pisa group and is expected to be installed in November, with about one month of delay respect to the original schedule. The developing group has been requested to provide a status report documentation for the second Virgo+ review, but any talks has been asked because this is not really a Virgo+ upgrade. The status will be

[1] In this field the total cost (from the beginning) of each project is reported

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reported during a weekly commissioning meeting since it is entering under the commissioning framework. Obviously, any sensitivity upgrade is expected by this device, but a better understanding of the thermal behaviour of the detector, fundamental for a more efficient correction by the TCS.

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/Virgo+/2ndReviewDocuments/Bigotta-PhaseCamera2ndReview.pdf
Cost (€)	32000
Status	Almost completed; delivery beginning of December
Responsible	S. Bigotta

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

This activity has been started 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 limitations, while maintaining full compatibility (interchange ability) with the existing modules. The desired improvements concern lower noise, higher possible incident light power (Virgo+ compatibility), lower DC offset (and resulting lower DC offset drifts), and changing the geometry from 'X' to '+' configuration. The concurrent request of higher power and lower noise, according to the Nikhef designers, can be satisfied only by producing two different modules optimized by each request. The production suffered a delay in the design phase but now a more accurate planning is available and the first prototype should be delivered in March, while the full production is expected for July.
The impact of this upgrade on the detector sensitivity could be not negligible and already important to reach the Virgo design sensitivity, as shown in the Figure 29, reporting a slide presented during the 2nd Virgo+ review.

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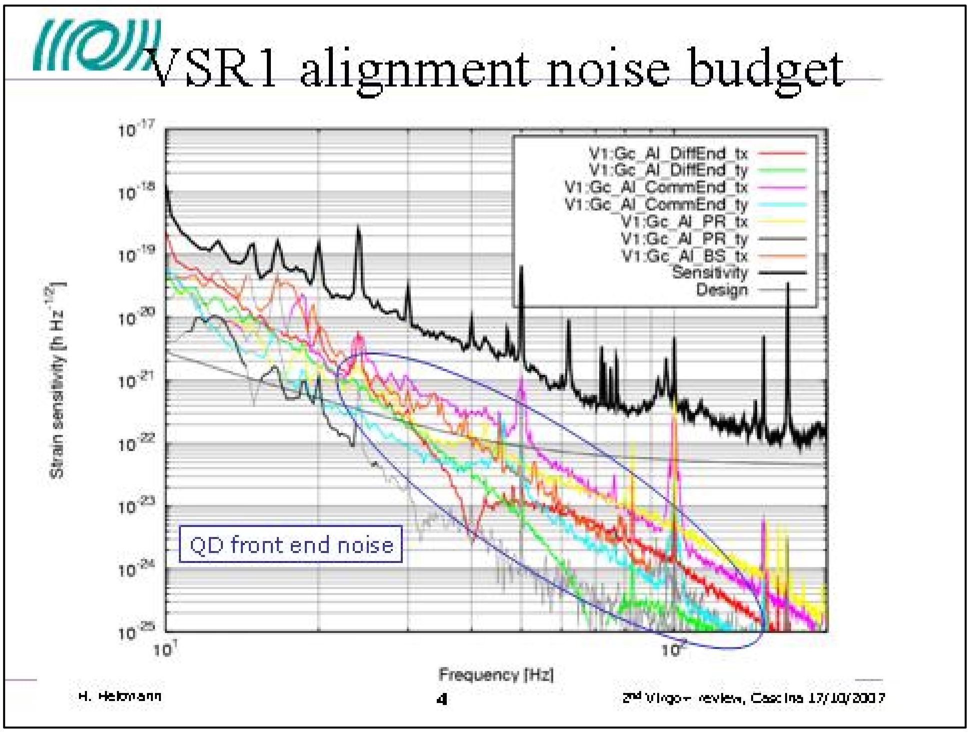

Figure 29 - VSR1 alignment noise budget

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	NA
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Heitm_071017_NewQuadrants.ppt http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/van_den_Brand.ppt
Cost	300000 (in the NIKHEF budget)
Status	Project suffered delays ; man power issue ; monitored through a planning meeting programme
Responsible	H. Heitmann

4.4.4.1 New coil drivers

The reduction of the Virgo noise, mainly at low frequency, requires also the reduction of the actuation noise. This reduction is attained only with a complex strategy (reallocation of the locking forces to the marionette, reduction of the dynamic range needed,…) and the renewal of the coil driver system in Virgo could play a relevant role.
The coil drivers currently used in Virgo have been patched several time in the Virgo commissioning to reduce the large 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 modification 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 2nd order filter). In addition, to reduce the long cable path connecting the DAC to the coil

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drivers, the new coil drivers are designed be equipped with a local DAC, digitally connected to the remote DSP. The production planning suffered a series of delays, but now is expected to start to mount (the analog part of) these devices in November; the DAC section is instead still undefined, because of an excess of noise at low frequency of the commercially available DACs. It must be noted that this activity started well before (2004) the Virgo+ project design, but now it is considered essential both for Virgo and Virgo+.

Name	New coil drivers
Code	Virchrq0052006
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0052006.html
Virgo+ review	*http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/Virgo+/2ndReviewDocuments/coildrivers.pdf*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/cd2ndrew.ppt
Cost	144000 (R&D included)
Status	Should be ready in November (at least one full tower); difficulties in having detailed feedbacks form the team
Responsible	A. Gennai

4.4.5 Detection photodiode "in vacuum"

In order to anticipate diffused light problem in Virgo+ which would prevent to reach the design sensitivity it has been decided to put the photodiodes under vacuum. Moreover, in case of DC readout the B5 photodiode will probably be used for power stabilisation and has therefore to be isolated from environmental noises For this reason it has been decided to investigate the possibility to move these PHD in the suspended bench inside the detection tower. These photodiodes cannot work in vacuum and will be inserted in closed boxes (containing air) with a remote motorized system. A prototypal production of the components is started and the production of the full system is expected to be compatible with an installation during the May shutdown.

Name	Detection photodiode "in vacuum"
Code	Missing
CRE document	Missing
Virgo+ review	*http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/Virgo+/2ndReviewDocuments/GranataTournefier_V+Rev2.pdf*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Granata_Virgo+Review2.ppt
Cost	30000
Status	In design phase
Responsible	V. Granata

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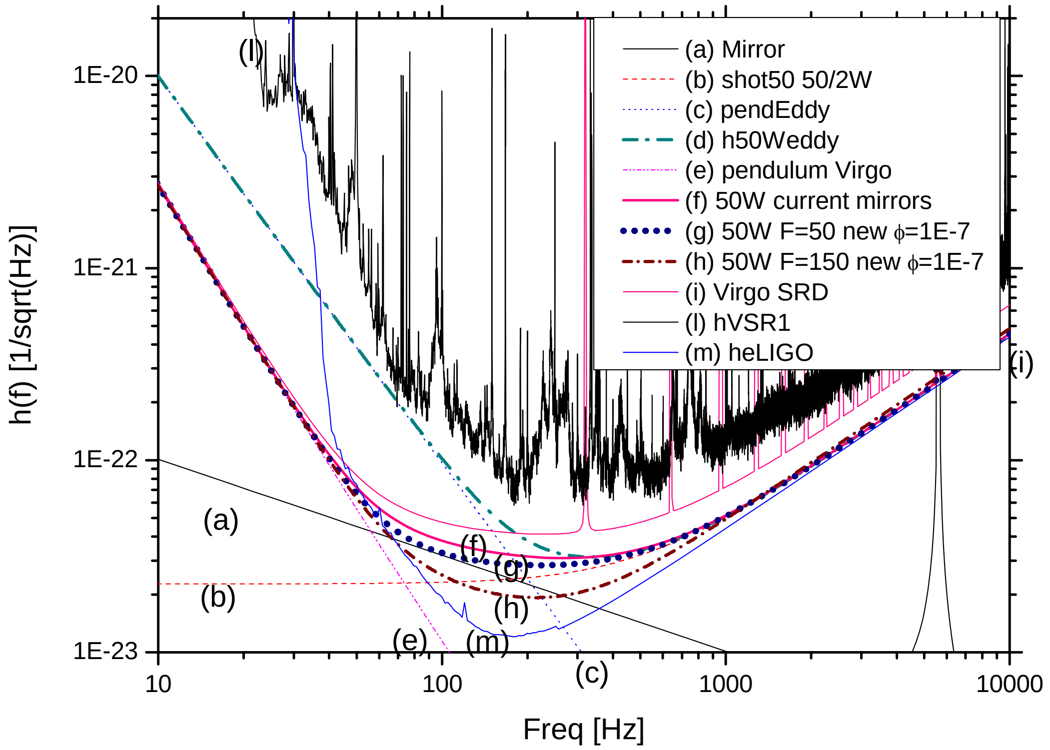

Figure 30 - Different sensitivity scenarios: the "relevant" curves are (l) VSR1 typical sensitivity, (i) Virgo nominal sensitivity, (f) target sensitivity upgrading "only" the laser and using a reduced (10^{-7}) substrate loss angle for the input mirror, (h) final sensitivity upgrading all the mirrors, increasing the finesse to 150 and upgrading the laser.

Table 1 - Average detection range (SNR>8) for NS-NS and BH-BH (Mchirp=8.7 solar masses)

Curve in Figure 30	Description	NS-NS (MPc)	BH-BH
	VSR1	4.0-4.5	
	Nominal Virgo with maximum eddy current effect	6.9	33.5
(i)	Nominal Virgo[2]	12.5	63.2
(d)	50W laser[3], maximum eddy current limitation[4]	8.5[5]	40.8[5]
(g)	50W laser, no eddy, current mirrors[5]	15.2[5]	76.2[5]
(h)	50W laser, no eddy, new mirrors[5], F=150	21.5[5]	108.7[5]
	Virgo+ with monolithic suspensions	49	250

[2] If we evaluate the Virgo nominal sensitivity with the input mirror substrate loss angle reduced to 10^{-7} we obtain 13MPc for the NSNS and 66 for BHBH.
[3] All the 50W, F=50 curves are computed with the real power recycling factor 40 instead of the nominal 50.
[4] To compute the eddy current limitation it has been used an analytical model that gives only an upper limit. The current noise projections are indicating that this expectation is probably over-estimated, promising a smaller eddy current limit (if any).
[5] **Nota Bene: the Virgo input mirrors are made in Suprasil SV 312. According to the Penn model, this material shows a loss angle frequency dependent with a value about 10^{-9} at the frequency of interest of the thermal noise. This model has been adopted to compute the curve (m) in Figure 30 and the relative detection distance in Table 1. For the mirror suspended with steel wires it has been adopted a substrate loss angle, for the same material, equal to 10^{-7}, with a conservative approach unjustified by any experimental evidence.**.

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4.4.6 Virgo+ upgrades: High power laser

The reduction of high frequency (>500Hz) noise in Virgo, as shown in Figure 28, requires the reduction of the shot noise, hence the increase of the power injected in the interferometer. The increase of the laser power is obviously the first step, but it causes a cascade of upgrades to have optics compliant with the new high power and requires that the TCS system is operational.

4.4.6.1 Laser Improvements

The core activity of this upgrade is the realization and implementation of a laser amplifier[6] 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; the integration of this system at the site is managed, instead, by EGO (E.Genin). The amplifier already undergone to the first commissioning phase in Nice and a reduced upgrade set has been defined (mainly the amplifier supplier). The completion of the tests is expected for January 2008. The integration optical components are expected to be ready in March 2008. The current amplifier, mounted in cascade to the Virgo slave laser, is able to supply up to 65W. The requirement selected for Virgo+ is to operate at 50W and all the injection optics must be compliant with this requirement. Nevertheless an effort to profit of all the available power is taken in account. In addition, since all the injection systems of the present GW interferometers show a large power loss, the sensitivities curve for Virgo+ are always computed with only 25W injected in the power recycling mirror. The nominal sensitivity improvement related to this upgrade is reported in the curve (f) of Figure 30, while the shot noise level is shown by the curve (b) in the same figure. The discrepancy in the 100-500Hz is due to the fact that the mirror thermal noise of Virgo (a) is expected to be dominated by the Brownian noise of the end mirrors, made in Herasil.
Obviously the introduction of the laser amplifier causes a chain effect[7] 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, superpolished mirrors) 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.

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/Virgo+/2ndReviewDocuments/Virgo+Review_Ampli50W_V+Oct2007Review.pdf http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/Virgo+/2ndReviewDocuments/Laser%20improvements%20Laser%20integration_Virgo+%20review2.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Cleva_16oct2007_Amplifier.ppt http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Genin_virgo+_2ndreview_Laserintegration161007.ppt
Cost	200000 (laser amplifier) + 50000 (integration)
Status	Well advanced ; no delays expected

[6] Essentially equal to the eLIGO one
[7] Mainly of thermal nature

Responsible	F.Cleva (Amplifier), E.Genin (Integration)

A quick overview of the related activities is hereafter presented.

4.4.6.2 Pre-MC realization

To reach Virgo+ design at high frequencies a PMC is might be needed to filter the power noise at 6 MHz.; furthermore, the PMC is useful to filter the jitter noise of the beam. One of the mirror of the PMC (under test) shown a wrong transmittivity and this requires a further step in the production process (ungluing, replacing of a mirror, test). The PMC should be ready in January 2008.

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/Virgo+/2ndReviewDocuments/Virgo+Review_PMC_V+Oct2007Review.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Cleva_16oct2007_PMC.ppt
Cost	15000 (only upgrade, project already funded in Virgo)
Status	Well advanced ; no delays expected unless accidend occurs in mirror replacement
Responsible	F.Cleva

4.4.6.3 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 recover the isolation factor, which is, in vacuum and having the beam aligned, lower than the nominal available. In fact, already with the Virgo laser and because of a thermal effect related to the tuning procedure the current FI shows an isolation factor lower than 1,000 instead of 10,000. Fringes between the ITF and the IMC are already visible, but currently they seems to not affect the ITF control. With the Virgo+ laser this isolation factor will drop below 100, because of additional thermal load, and this cannot be accepted. 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 upgrade will be ready to be installed in Feb 08.

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/Virgo+/2ndReviewDocuments/CorrectionofthermaleffectsinSIBFI_Virgo+secondreview_last.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Genin_virgo+_2ndreview_Faradayisolationimprovement_161007.ppt
Cost	8000
Status	Production almost completed; test in lab expected in December; late the lensing compensation part (not urgent).
Responsible	E. Genin

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4.4.6.4 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 λ/2 waveplate placed before the first Faraday isolator on the LB. The aim is to have a remote control of the ITF input power for a variety of purposes, and in particular to increase the flexibility of the locking procedure. This component will be installed during the Virgo+ laser amplifier integration. For historical reason the CRE is separated from the laser integration CRE.

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
Cost	4000
Status	Ready
Responsible	E. Genin

4.4.6.5 New end mirror payload of the IMC

The end mirror of the input mode cleaner (IMC) is suffering of optical (low quality of the substrate and of the coating, large scattering) and mechanical (excessive lightness of the mirror and of the reference mass, radiation pressure effects, control issues) problems. These problems affected Virgo for many years and have been patched thanks to the detector and commissioning activity (but, still at the output of the IMC are delivered only 8W of the 12.5W injected). In fact the upgrade of the injection bench permitted the insertion of the Faraday Isolator that suppressed the fringes due to the scattered light and the understanding of the spring effect due to the radiation pressure on the small mirror permitted a more accurate control. That patching is not anymore effective in Virgo+ (because of the larger power) and it has been decided to replace the test mass with a new mirror (heavier, better quality) and the payload with a heavier reference mass. The installation of this device is expected during the long May 08 shutdown.

Name	Replacement of the MC payload
Code	Virchrq0032006 (old version)
CRE document	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0032006.html
Virgo+ review	*http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/Virgo+/2ndReviewDocuments/IMC_10_10.pdf*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Thomas_IMC_Oct_2007.ppt
Cost	27000 (NIKHEF budget) + 20000 (EGO budget)
Status	Production of components just started
Responsible	J. van den Brand

4.4.7 Change of the modulation frequency

Virgo is currently adopting the Anderson frequency as main modulation: the 1st higher order mode (TEM1) of the Upper Sideband is resonant in the FP cavities when the fundamental mode of the carrier is also resonant in the FP cavities (Fmod=6.2643MHz). In this way some alignment signal available in transmission of the long FP cavities. A recent huge effort, using both Finesse and DarkF demonstrated that, in presence of high absorption of the mirrors, this could cause instabilities in the detector.

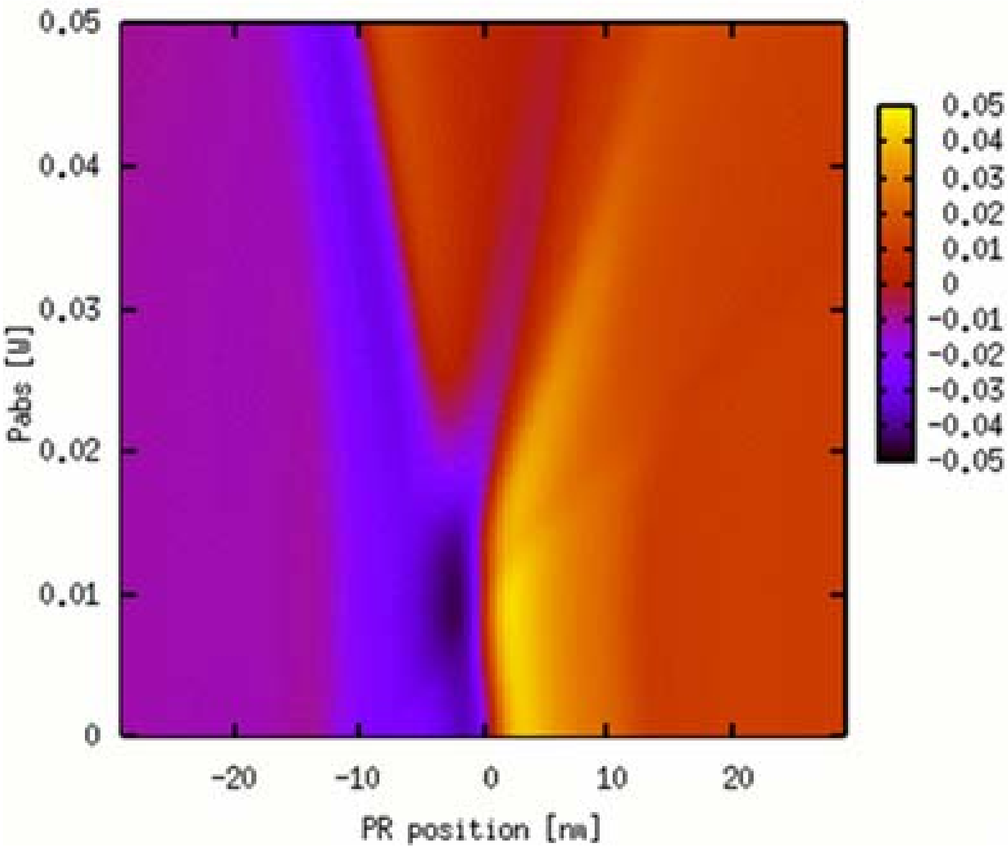

Figure 31 - PR longitudinal error signal for a double cavity with respect to the power absorbed by the Input mirror (Fmod =Anderson). As the thermal effect increases, a second zero appears in the error signal

As shown in Figure 31, as soon as in absorbed power increase above a certain threshold a second (and a third) zero appears in the PR error signal. This problem could be completely solved if we escape from the Anderson frequency and we adopt the so-called Nominal frequency (Fmod=6.2709MHz), where both sidebands are symmetrically anti-resonant in the FP cavities (sidebands have then the same properties of resonance in the FP cavities). I must be noted that the TCS system should contribute to mitigate this problem, but other issues are pushing to adopt the Nominal modulation frequency: decoupling of PRCL and MICH degree of freedom, optimal recycling length will correspond to the max decoupling of PRCL and MICH, optimal recycling length independent by the Finesse of the FP cavities. Although there is a general consensus in escaping from the Anderson frequency, still is undecided which new frequency to select. In fact, meanwhile a small displacement (few hundred hertz) respect to the current frequency will have a small impact on the infrastructures (but an uncertain usefulness), the selection of the Nominal frequency will imply the displacement of one (end IMC) or more towers, with a shutdown period of about one month and a longer recovery.

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Furthermore, the new alignment strategy is still undefined. This postponed the decision and a review meeting on this subject has been located at the end of November.

Name	Change of the modulation frequency
Code	Na
CRE document	Na
Virgo+ review	*http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/Virgo+/2ndReviewDocuments/Marque-Anderson-Review2.pdf*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Marque_161007_Frequencymodulationchange_VirgoPlusReview.ppt
Cost	Na
Status	Still in the conceptual design phase
Responsible	J. Marque

4.4.8 Monolithic suspension

As always stated, 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 in the frequency range 5-60Hz, through the use of a monolithic fused silica design of the mirror last stage suspension. This limitation is still not effective because the current detector noise level well above the nominal curve in that frequency regime. In Figure 32, the pink curve (the most appealing!) shows the potential noise level reachable by Virgo+ if the suspensions are realized with monolithic fibers , the mirrors are replaced with Suprasil substrates and the finesse is increased to 150 (see next section). In reality that noise is not accessible because a fundamental noise level, caused by the so-called Newtonian noise or gravity gradient noise, limits the sensitivity to the blue curve (labelled "*as above and Newtonian noise*"). Furthermore, the actuation noise could play a fundamental role, even is its prediction is difficult the realize because it depends by a complex strategy, as previously stated. Hence, the dotted red curve[8] in Figure 32 must be considered only as a "warning".
The Perugia, Roma, Firenze team, with the support of the EGO infrastructure, developed the fiber production facility, the design of the upper clamp, the marionette and the reference mass compatible both with the fused silica and the standard steel wire suspension. But the several mounting attempt shown problems in the reliability of the solution and it has been impossible until now to certify the obtained suspension with robustness and control tests. The described difficulties prejudge the possibility to install this solution in a early Virgo+ scenario.

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/Virgo+/2ndReviewDocuments/Monolithic-Virgo+Second_Review.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Puppo_16102007.ppt
Cost	434000
Status	Late ; incompatible with the 2008.5 shutdown and with the 2009.5 science run

[8] Realized with a reduction of a factor 3 respect to the current DAC and a reallocation of a factor 2 of the force to the marionette.

Responsible	H.Vocca

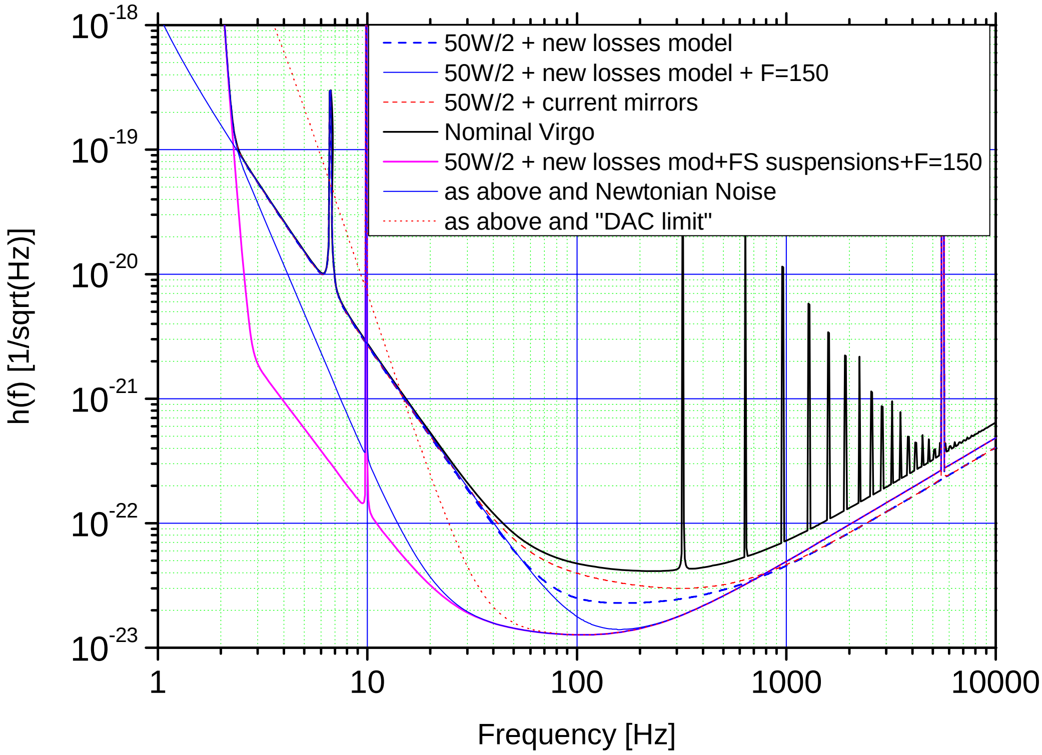

Figure 32 - Different sensitivity scenarios, including the monolithic suspensions

4.4.9 New mirrors

Several reasons are pushing for the replacement of the long cavities mirrors:

1. current mirrors are probably polluted by the installation procedure and a cleaning operation[9], effected in tower, probably will not recover the full performances
2. the magnets in the input mirror are mounted with parallel polarity, meanwhile the minimization of the magnetic dipole requires pairs with anti-parallel orientation. Furthermore the magnets are a factor 5 more intense of the original design and this increase the coupling with the environmental magnetic noise
3. the end mirrors have no anti-reflecting coating in the back face. This causes (measured) multiple beam scattering in the end benches.
4. end mirrors are made in Herasil, cheap but mechanically dissipative material; its thermal noise should limit the sensitivity of the detector if a 50W laser is adopted. If all the mirrors are replaced with Suprasil substrates and the coatings are made with the new Ti doped solution, the expected thermal noise is reduced (80-500Hz), permitting the sensitivity curve named (g) in Figure 30. It should be mentioned that the promised level of thermal noise could be spoiled by the frictional losses between the mirror and the suspension steel wires, if a standard steel suspension is adopted. This is the reason why the replacement of the mirror has been always located in the monolithic

[9] Expected at the end of November

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suspension framework, but it could keep its validity also in a standard (well made) steel suspension scenario.

5. if the thermal noise model for the Suprasil is adopted and the new coatings are used, the dominant noise in the 80-500Hz becomes the shot noise of the 50W laser. In this case, a better performance can be obtained increasing the finesse from 50 (Virgo) to 150. In this case the curve (h) of Figure 30 is obtained. It is important to underline that in this way the eLIGO curve (m) in Figure 30 is matched in the central region, while the reduced power recycling factor caused by the increased losses slightly spoils the sensitivity at high frequency. It must be recalled, at this point, the conservative approach we adopted to compute the shot noise (only 25W injected in the ITF). Obviously the increase of the finesse implies the replacement of the mirror.

Using spare Virgo mirrors and new substrate previously ordered a new set of mirrors for Virgo+ is under production. The (end) substrates are under polishing (delivery in November) and will be coated by LMA with an higher reflectivity (F=150). The preparation of these mirror for the installation in the ITF requires several months of work. It is important that a decision on the Virgo+ baseline is quickly taken.

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/Virgo+/2ndReviewDocuments/MirrorsFPVirgo+_2ndReview_v0.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Flaminio_Mirrors_for_Virgo+_2ndReview.ppt
Cost	120000
Status	In schedule
Responsible	R.Flaminio

4.4.10 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 computing power of the DSPs, differential ADC for all the channels…) defined thanks to the commissioning activity

4.4.10.1 New timing 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 and new differential and fastest ADCs. It is obviously difficult to evaluate the impact of these upgrades on the sensitivity (although differential ADC will improve the electrical noise immunity). Surely they should contribute to the detector stability, solving the problems occurred during the Virgo commissioning and science run (GC crashes,…)

The GPS receiver it is already defined and two new devices have been ordered. The TDBox and MUX/DeMUX production will be completed in January, while the TOLM will be deliverd in Mars. More critical is the production of the ADCs since the delivery is expected in May and it could be affected by production delays. The installation will be partially realized

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as parallel operation during the spring 2008 and will be completed in the long shutdown expected in May-July 2008.

Name	New Timing and DAQ electronics
Code	*Virchrq0082007*
CRE document	*http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/CRE/virchrq0082007.html*
Virgo+ review	http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/Virgo+/2ndReviewDocuments/Masserot-Control-DAQ-Review2.pdf
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/Masserot_Contol-DAQ-Review2.ppt
Cost	387000
Status	All components are in the expected schedule. Possible delay by the ADCs production that should be completed during the 2008.5 shutdown
Responsible	A. Masserot

4.4.10.2 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. Also in this case it is impossible the evaluate a direct noise reduction sue to this upgrade, but 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. 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	*http://wwwcascina.virgo.infn.it/collmeetings/DMwebpages/Virgo+/2ndReviewDocuments/DSP.pdf*
Most recent document	http://wwwcascina.virgo.infn.it/collmeetings/presentations/2007/2007-10/Virgo+2ndReview/dsp2ndrew.ppt
Cost	161000 (including R&D)
Status	Components should be delivered just in time; difficulties in having a detailed planning.
Responsible	A. Gennai

4.4.11 Infrastructure upgrades

In addition to the described activities, a series of infrastructure upgrades are planned for Virgo+ and have been described in the Virgo+ review. That activities should be discussed in the EGO report.. They are mainly devoted to the cleanliness in the EGO clean rooms and to the reduction of the environmental noises.

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4.5 Planning

Some of the upgrades described in the previous section (cryo-trap, TCS) are expected to be installed between Feb08 and Mar08, together to other commissioning activities (end benches reshuffling, fast quadrant centering system installation). The commissioning needed to understand these upgrades pushes the remaining installations to the May-July 2008 period, when all the production tasks should be completed. Monolithic suspensions will be not ready for that time window and the time needed to commission them precludes any other time slot before the start of the Virgo+ science run, if it is confirmed for middle 2009. For this reason two options are available to the collaboration (keeping fixed the science run start date);

- to keep the current mirrors (if the cleaning procedure is effective, the eddy current noise is not present or mitigated, the wrong polarity of the magnets is not a problem or mitigated) pointing to start the science run with a sensitivity described by the curve (f) in Figure 30 and the NS-NS detection distance of 13.2MPc (see Table 1).
- to replace the Virgo mirrors with the new one, adopting a standard but improved steel suspension (no more eddy current, right magnets polarity and intensity) pointing to the sensitivity (h) of Figure 30 and to a detection distance of bout 28MPc. In this case additional production (new reference masses) is necessary and a longer commissioning could be necessary

The decision must be taken, within the end of 2007, considering which is the scientific goal that the collaboration want to attribute to Virgo+.

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5 Data analysis report

5.1 Services and tools

The large data production during the VSR1, as well as the need to share processed data with the LSC, has stimulated several activities on data replica and metadata handling.

5.1.1 Data Replica

The replica of Virgo data from Cascina to the Computing Centers is running smoothly using perl scripts which run bbftp transactions.

The Virgo rawdata are transferred automatically to Bologna, and from there to Lyon. These data are not copied to the LSC presently.

The Virgo processed data (the h-Reconstructed data sets + auxiliary information, about 3 Mbps) are also transferred to Bologna and Lyon, and simultaneously relayed to the Caltech HPSS system, from where they are distributed to the LSC using LIGO tools.

The reverse path for transferring processed data from LIGO to Virgo is using the same Virgo tools. Unfortunately, in this case several problems have arisen.

A first major issue resulted from the nature of LIGO frame data, which are organized in small files; these are very inefficiently handled by HPSS systems, and prevented to make the transfer directly to Lyon. The solution chosen was to make the transfer to Cascina, were data could be reorganized in larger files.
The automatic transfer then was set up and run initially smoothly; then during the summer the transfer became slow and actually stopped. The cause of the problems has been tracked to the difficulty for Virgo tools running at Caltech to retrieve data from the Caltech SAM-QFS system; both the building of the lists of files to be transferred, and the access to individual files, are very slow as soon as the files are not in the disk cache of the SAM-QFS, but are instead on tapes.

Modifications were required to make the transfer scripts robust against failures of the tapes or time-out in accessing files, and the transfer has been restarted without however being able to catch up with the data production.

Recently it has been understood that a way out is to access directly the data cached on the LIGO LDAS cluster, and this source is being used to accelerate the transfer of the portions of data prioritaires for the analysis groups.

However there is a definite need to improve substantially the transfer method; the best option is probably to use the LIGO Data Replica tool, we understand better adapted to access data on SAM-QFS, to transfer data to Virgo. This solution could work in the mid-term, for the post-S5 era.

Over the horizon of VSR2/S6, LIGO and Virgo are bound to develop a common solution using grid tools compatible with both the European and U.S. flavors of grid.

5.1.2 Data distribution

With the restart of the commissioning after the end of the VSR1, the circular disk buffer dedicated at EGO to the temporary storage of raw data will have to store the most recent data,

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hence the VSR1 data will be progressively overwritten. These raw data remain available at Lyon and Bologna, for users logged on the Virgo machines at the computing centers. However, it is important for the commissioning crew to access those data in a way as similar as possible to the one adopted when working with data stored at the site.
To this end, a server has been set up in Bologna (called *dataSender*) which can receive requests from clients, like the visualization tool *dataDisplay*, and send streaming channels extracted from the frame data. Once the VSR1 data set in Bologna will be consolidated and indexed, this service will entirely subsidiate the access to the VSR1 raw data set at Cascina.
The same kind of server is being set up in Lyon, thanks to a middleware (XrootD) allowing to access data stored on hierarchical storage systems in a way similar to the direct access to spinning media storages.

5.1.3 Bookkeeping database

The Virgo Bookkeeping Database is online at the address
https://virgo.pg.infn.it/VDB/main.php
It is designed to receive information about the location of files in the different data repositories of the Collaboration, and to organize the information in a mySQL database which can be queried in different ways. The information comes from daemons monitoring the file lists available at the different locations.
The database is also able to store information about the data quality and the data segments, as well as to include tables of events and vetoes. The procedure for storing this information has been defined, and allows to post temporary lists which can then be promoted to production after having been reviewed by the responsibles of the database.
The information can be cross-correlated in different ways, and the results can be exported in tables and towards the LIGO database.
Some parts of the database web interface is still under development, but is already usable for production.

5.2 Offline computing in Bologna and Lyon

We recall that the off line computing for Virgo is performed in part at 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.

5.2.1 Virgo at INFN Tier1-Bologna

The Bologna Cnaf is used both to store data, mostly on spinning media for immediate use, and to perform offline analysis on the Linux computing cluster.

To free space on spinning media for VSR1 data, the data taken during the commissioning runs have been moved on CASTOR plus, for a total of 12 TB of data now stored on that system.
Then, data collected during the Weekly Science Runs (with the exception of WSR 8-9-10) and the VSR1 are stored on spinning media, under the gpfs file system.

Status of the storage
At present in Bologna the Virgo collaboration has available
103 Terabytes, of which 96 TB are dedicated to data and 7 TB to processed data and user space.
Of the assigned space,
88.6 TB are used
22.7 TB are available.

However , we still have:

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a) to move 5 TB of VSR1 data stored in the 7 TB dedicated user disk-space
b) to transfer from Cascina
- the WSR 8-9-10 (~5TB)
- trend data and 50 Hz data taken from the 15th January up to now (~ 4TB)
- the selected LIGO and GEO data taken in coincidence with the VSR1 data.. (??)

CPU utilization
Concerning the CPU amount used in Bologna, the CNAF monitor reports
N.job=16654 corresponding to 1457 kSI2000*day.
These are mainly used for the full sky pulsar analysis based some WSR run and on the first step of the hierarchical search.

Then we have to consider also the computation carried on applying the coherent approach on a small bandwidth. These are MPI jobs running continuously for 4 months on ~100 CPUs. However, the CPU monitor of MPI jobs is not working properly in Bologna, hence at present we have just a reasonable guess about this large amount of CPU time 5400 kSI2000*day
Although we need to check again this number with CNAF-Bologna, at present we evaluate our total CPU consumption in Bologna at 6857 kSI2000*day

5.2.2 Virgo at CCIN2p3 - Lyon

Lyon computing center (CCIN2P3) is used to store permanently the Virgo data. That includes:

- all streams recorded during data taking periods since the first commissioning run (E0);
- all 50Hz files since 2002;
- all trend data files since 2001.

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.
A Linux server dedicated to the Virgo data replica is now available in Lyon CC.

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 submitted through Grid. We summarize the Virgo resources used in Lyon, as of October 17^{th}:

Storage:
128 TB used in HPSS for all data taking periods since 2001
300 GB on disk for users

CPU:
Use of the CPUs since 2007 January 1st: 19800 kSI2000.day (our request for 2007 is 50000 kS2000.day). Virgo consumption represents 3% of the total CPU consumed by all the other experiments performing data analysis in Lyon.

5.3 The analysis activity of Physics groups

We recall that in Virgo we have organized four Physics groups, by now closely interfaced and actually joint with the homologous LSC groups, with different scientific targets:

Burst signal search
Coalescent Binary signal search
Pulsar signal search

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Stochastic background signal search

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, and *Detector Noise* study group.

The activity of the joint LSC-Virgo search groups is reviewed by the Review Committees, whose activity we detail in the sections addressing each search group.

5.4 Calibration and h-Reconstruction

During VSR1, automated calibration data taking were running every week. It has allowed to monitor the detector stability and to reduce the statistical errors of the measurements, in particular of the mirror actuator gains. The frequency dependent transfer functions of the actuators have been stable during the run within less than 5%.

Post-VSR1 calibration data have been taken in order to check some measurements. These measurements are under analysis. Their main aim is to measure the mirror actuation gains of the suspension in "Low Noise" mode. Different sort of data have been taken in order to cross-check the results. Preliminary analysis indicates an unexpected difference of the order of 10% between the actuation gain in High Power mode and in Low Noise mode.

New measurements were also performed during post-VSR1 shifts. In particular, the calibration of the NE and WE marionette actuation is of main interest in order to improve the reconstruction at low frequency (10 to 50 Hz).

Another method is being developed to calibrate the mirror actuator gains independently, using the radiation pressure of a secondary laser to push on the input mirrors.
Few data were taken with the so-called photon calibrator before the run, in May 2007. They allowed to fix the convention of the sign of the strain h(t) in relation with the Ligo convention (see note VIR-018A-07). Also, the actuator gain calibration was in agreement with the classical calibration, but the systematic errors were of the order of 50% (see https://workarea.ego-gw.it/ego2/virgo/data-analysis/calibration-reconstruction/auth-only/optical-calibrator/first-absolute-calibration-using-the-ni-photon-calibrator-may-2007).
A fraction of the post-VSR1 calibration shifts were dedicated to the calibration and better understanding both NI and WI photon calibrators. The data are under analysis. The aim is to provide a calibration of the actuator gains better than 25% to cross-check with the classical methods.

The online reconstruction worked properly during the run after some upgrades at the very beginning of the run as reported in the previous report. A reprocessing of the data is scheduled when the calibration parameters will be improved with the latest data. Future versions of the reconstruction should handle of the control signal of the NE and WE marionettes, improving the accuracy of the reconstruction below 50 Hz.

The activity of the calibration group is being reviewed by a Virgo review committee, and is also regularly discussed with the LIGO calibration group.

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

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5.5 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.

5.5.1 Analysis of C7 data

Analysis of C7 data is now completed. Three papers are about to be submitted .One concerns a search in coincidence with the gamma ray burst GRB050915a that occurred during the run. A second is an "all-sky" search in the frequency band [150Hz, 2kHz], with astrophysical interpretation of the search results (upper limits) in particular in the context of recently predicted supernova signals and recent black hole –black hole merger waveforms as well. The last one reports on the coincidence analysis with resonant bar detectors which were on also during the C7 run.

5.5.2 Analysis of VSR1 / S5 data

Virgo and LSC burst groups have now merged and all analyses are now joint ones. During the run a burst pipeline (Q-pipeline) was online and allowed to make quick analysis and checks. The entire run has been then reprocessed with the same Q pipeline (because of unavoidable problems during online processing) and processed also with the Peak Correlator (PC) pipeline. We have then at the moment at disposal 2 complete sets of triggers generated by two independent pipelines. Other pipelines are also planned to process the data (VSR1 and joint period of S5 as well):, including EGC.

Other pipelines have been run on environment and sensitive channels, like the HACR algorithm which provides a time-frequency representation of data.

From the Virgo side we have mainly put our effort on VSR1 data characterisation: Data Quality flags, study and interpretation of loudest events, set up of first vetoes for subsequent burst analysis.

A primary list of DQ flags is already available. The HACR triggers on BS_BMS_XXX channels (beam monitoring system channels) have been used to veto some of the dark fringe (Q pipeline for the moment) triggers for the period May 18th – July 18th (problem on BMS piezo which has been identified and then fixed on July 18th which gave loud transients on the dark fringe signal around 200 Hz).

Meanwhile we have defined a restricted period of S5/VSR1 for prototyping our joint studies and combined analysis (explicitly the first week of August). The amount of lifetime of the network L1-H1-V1 for this week is about 65%. The Q and PC pipelines are currently used for this first analysis. Results to follow (preliminary results will be shown on October LSC-Virgo meeting).

Concerning the searches triggered by external astrophysical signals, we are participating to the combined study of coincidences with gamma ray bursts. Two GRBs, namely GRB070520b and GRB070729, have been identified for a first joint study (all the interferometers were in science mode around these GRB events).

The Virgo component of the review committee attached to the burst group is currently focused on the review of the searches performed on C7 data, while also following the joint LSC-Virgo activity.

5.5.3 Concerns

The data transfer of S5 data from Caltech to Europe. At the date of October 15th we are far from having LIGO data in our CC, while our LSC colleagues have the VSR1 processed data in the Caltech CC. The situation is unfortunately very asymmetrical.

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5.5.4 Link

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/

5.6 Coalescing binaries group

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

The effort to develop code able to perform network coherent analysis for inspiral signals has been pursued, by exploring various methods of extracting the source direction by combining coherently the matched filtered signals of individual detectors.

We went through the review process for the paper "Improving the timing precision for inspiral signals found by interferometric gravitational wave detectors", which had been accepted for publication in CQG as part the GWDAW 2006 proceedings.

The WSR8 data were used to gear up the joint LSC-Virgo analysis as a small scale test with real data, prior to both collaborations going to full data sharing. The WSR8 and coincident S5 data were coincidently analyzed using Virgo software, and this work was presented at the Amaldi conference.

A triggered search was performed on the data coincident with GRB 070219A - which occurred during WSR9 - and this work was presented as a poster at the Amaldi conference.

Much effort was dedicated to analyzing the VSR1 data during the run. Both the Merlino and MBTA pipelines ran online a BNS search covering the [1-3] $M_\odot$ mass range, and the associated monitoring was provided to scientists on shift to assess the quality of the data. The members of the CB group also monitored the output of the on-line search to help characterize the data and give useful feedback to plan actions on the detector, and to identify sources of loud triggers in order to initiate the veto studies. Now that the run ended, the detector characterization work is focusing on the veto studies based on auxiliary channels to provide exclusion lists to be used by the inspiral search.

The VSR1 data are going to be analyzed together with the S5 data, by the joint LSC-Virgo CBC group. The second month of VSR1 has been identified as our initial target to gear up the joint analysis. Basic information was provided to allow the LSC members to handle the Virgo data and start analyzing them. The Virgo MBTA pipeline is being modified to be able to handle the LIGO data in a sustainable way, and the simulation tools are being tailored to be able to generate software injections over a few months time scale.

The review committee attached to the coalescing binaries group has not yet started a regular activity.

5.7 Pulsar Group

The group activity is focused on recent data from VSR1 and on the integration with the LSC CW group.

5.7.1 Analysis of VSR1/S5 data

The analysis pipeline for the non-targeted search has been further developed, including a new event subtraction procedure, which subtracts large glitches in the data instead of vetoing the noisy period.

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Then the pipeline has started to be run on VSR1 data, including the following steps

- Preprocessing of the data, created the so called "reshaped sds" files for VSR1, up to the beginning of August
- Continue the analysis over 10 days of VSR1, including
  - Population of the Short FFT data base in the band 0-2000 Hz, including the new event subtraction procedure
  - Generation of the Peak map of significant events in the time-frequency plane.
  - Cleaning of the peak map cleaning (new cleaning procedure)
  - Definition of the candidates in the band 50-1050 Hz.

Then a new Hough transform procedure is under study and will be applied on the candidates.

The search for signals emitted by known sources is still under development and enhancement: the new event subtraction procedure is being integrated, as well as new preprocessing procedures, including a different low-pass filter.

5.7.2 Ligo-Virgo joint work

The activity is ongoing, with weekly phone conferences with the LSC CW group.
The new event subtraction procedure has started to be applied on data from the 4km LIGO Hanford detector.

5.7.3 Other activities

The review committee for the continuous waves searches has started its activity with a series of meetings dedicated to review the different portions of the search pipelines. The activity of the NIKHEF group has started to be integrated and coordinated with the one of the Rome group (S.v.d.Putten visited Rome for 1 week) . Work on the documentation has been carried out, in particular the PSS_UG user guide has been updated.
Most of the activities are documented in the PSS_UG and in the reports available under http://grwavsf.roma1.infn.it/PSS/

5.8 Stochastic Background

The activity of the group is totally dedicated at the LSC/Virgo collaboration.

5.8.1 Work on simulated data

The analysis of simulated injections in noise from the LIGO-Virgo project1b data (simulated data) has been completed. The results have been presented at the Amaldi conference, and will be published in Class. Quant. Grav. (paper accepted).
The main conclusion is that LSC/Virgo pair can give a negligible contribution to the S5 upper limit over all the frequency band. However it give a relevant contribution to the sensitivity above 800 Hz.
This situation will improve when the design sensitivity will be reached by Virgo in the low frequency region.

Concerning targeted searches, the contribution of Virgo to this kind of search is of the same order of magnitude of the LSC pair, though not the dominant one (with the exception of direction around the pole).

5.8.2 VSR1 data analysis

A preliminary analysis is started. Until now it was performed on the caltech cluster, and on a small first fraction of the data. It will be extended in the immediate future to the complete dataset, using computational resources in Cascina and Bologna. The possibility of using the GRID farm in Pisa is not yet confirmed.
A session of synchronized hardware injections has been performed. Two stretches of simulated stochastic background (20 minutes each) have been injected simultaneously in Virgo, Hanford and Livingston detectors. The first stretch contained completely correlated white noise. The second one is a stochastic background signal with the correct cross correlation and a linearly rising spectral density. The analysis of these data is currently in progress.

The review activity on the stochastic background is still ramping up.

5.9 The Noise group activity

During VSR1 the Noise group components had access to the interferometer only for a few shifts to perform experiments. Most of the outcome was of immediate use to improve the detector sensitivity and is reported in greater detail in the commissioning report. The large amount of data available allowed several other analyses that were reported in a post run meeting.
Dark fringe long term non stationarity is under investigation in different frequency bands (below 100 Hz, 100-1000 Hz, above 1 kHz) and should allow to give some hints on the path and the source of the noise for each band. This could be done systematically making a regression of noise level in frequency bands with trend data of auxiliary channels. The regression works well, being quite predictive in following the dark fringe noise level.
The catalogue of lines present in the dark fringe, as well as the work of identification of their origin is progressing well. Also the influence of environment was demonstrated during a power cut off that turned off all the air conditioning for 90 seconds. This allowed to identify part of the equipments that are introducing noise in the sensitive areas like the laser laboratory or the detection tower Brewster.
The introduction of a new UPS and the harmonics corrector was shown not to be harmless. On the same subject of electromagnetic coupling a thorough investigation took place to remove sources of varying magnetic field near the mirrors, with success.
The line problem was attacked from the analysis side by the pulsar group, who found many lines, several of them coinciding with environmental signals.
Some experiments took place shaking the top of suspensions, simulating bad weather, showing the different influence of the Input Bench and long suspensions motion, as well as the good performance of the suspension system with respect to these series of experiments.
High SNR data have been studied, and coincidence with environmental channels was found.
The relevant presentations can be found by looking at
https://workarea.ego-gw.it/ego2/virgo/data-analysis/noise-study/meetings/2007-meetings/noise-2007-10-18
After the run, work based on the analysis of VSR1 data will continue so that a deeper understanding of noise sources and nonstationarity can be reached giving better confidence in the data analysis and helping to improve the detector performance.

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6 Outreach Report

6.1 Newspaper and magazines

Among the several articles triggered by the May press conference, the most recent one was on the Sepember issue of Science et Vie.

After the short news about the start of the first joint Virgo/LIGO science run, published on the July-August issue of CERN Courier, they accepted a more extended article, to be published on the December issue. It has been written by Riccardo Desalvo (LIGO) and by Carlo Bradaschia (Virgo), after the end of the successful joint run, enhancing the relevance of the worldwide network of gravitational wave detectors.

The next issue of "Asimmetrie" (the INFN newsletter, in its new monographic version), will be completely devoted to gravitational waves including Virgo, of course.

6.2 Virgo/EGO newsletter

"h – the gravitational voice" continues to be regularly published on the web, every quarter. The sixth issue recently appeared on the web (http://www.ego-gw.it/public/hletter/hletter.aspx), includes "Histoire d'h": an article by Paolo LaPenna on the origin of the use of the letter ***h*** for the dimensionless amplitude of gravitational waves.

6.3 TV

The series "The Cosmos – a beginner's guide" has been broadcast by BBC2 in August and September. It contained a nice 20 minutes video on Virgo, turned last year at EGO.

6.4 Public relations

The issue of public relations and science popularization will be debated at the LSC/Virgo joint meeting in Hannover (October 20-25), with the aim of better coordinating the different efforts.

On Monday, October 29, EGO and Virgo will be visited by Kathy Svitil, Caltech Media Relation delegate, coming from Hannover. The same day, on the site, will take place the presentation of a DVD on General Relativity, developed by Mauro Francaviglia, former chairman of the Italian Society for Relativity and Gravitation.

6.5 Site visits

Will restart on a regular basis in November.

6.6 Exhibitions

We have been asked to build a small interferometer for an INFN travelling exposition called "La Natura Si Fa In Quattro"; it will be ready in November. Provisionally an existing device has been given on loan.

7 Manpower Statistic

This section reports on the summary of the Virgo Manpower. This is a compilation of the 2007 Memorandum of Agreement between the groups and the collaboration. This detailed information is available in the Virgo codifier (https://pub3.ego-gw.it/codifier/). The MoAs, and therefore the following tables are covering the period October 1 2007 to September 30th 2008.

Since part of the collaboration members have teaching duties, this could reduce a little bit their research time. This factor is difficult to estimate and fluctuate from person to person. The first table has been built assuming a 75% effective time for research for persons with teaching duty. The get an idea of this effect on the number of FTEs, a second table has been build assuming a 100% time available for research.

Group	Persons	FTP	Student	Authors	FTE	V	V+	AdV	DA	Other
Annecy	18	11	0	12	14,6	3,1	8,2	0,3	3,1	0,0
Artemis	14	5	2	12	10,2	1,4	2,8	3,0	3,0	0,0
Firenze	10	6	2	10	8,2	1,8	1,5	3,5	1,5	0,8
Genoa	8	0	1	3	2,7	0,4	0,8	1,5	0,0	0,0
LMA/ESPCI	12	0	1	8	4,6	0,4	2,5	1,6	0,1	0,0
Napoli	15	1	4	10	7,0	1,8	0,1	2,7	2,5	2,0
NIKHEF	7	0	1	4	3,6	0,5	1,3	0,0	1,8	0,0
Orsay	7	5	0	8	5,6	0,7	0,0	1,5	3,4	0,0
Padova-Trento	4	0	0	4	1,9	0,2	0,0	0,0	1,7	0,0
Perugia	10	2	2	9	3,5	0,5	1,0	1,1	1,0	3,2
Pisa	24	6	7	22	14,4	2,6	2,5	4,1	5,3	4,4
Roma I	16	7	2	9	11,4	1,0	2,7	2,9	4,7	0,0
Roma II	10	0	2	8	6,6	0,0	2,7	2,1	1,8	0,0
Total	**155**	**43**	**24**	**119**	**94,1**	**14,2**	**26,0**	**24,1**	**29,8**	**10,3**
EGO	32	25	0	21	28,1	18,1	6,2	1,9	1,9	
Total	**187**	**68**	**24**	**140**	**122,2**	**32,3**	**32,2**	**26,0**	**31,7**	**10,3**

Table of the manpower dedicated to Virgo, assuming that persons with university duties are spending 75% of their time on their research activities.

Remarks:

- FTP is the number of person (including the one with teaching duties) who are working full time on Virgo, excluding the students (who usually are 100% on Virgo).
- The V column quotes the FTE spend on the current Virgo detectors (commissioning activities, services activities,…)
- The V+ column quotes the FTE working of the preparation of the Virgo+ upgrades.
- The AdV column quotes the FTE working on the preparation of the Advanced Virgo, (baseline and possibles options)
- DA is for data analysis
- The column “other” includes activities that are not part of the Virgo/V+ or Advanced program (like the cryogenic activities), but are listed as Virgo contribution in the institution list. These activities are not included in the total FTE which is just the sum of the V, V+, AdV and DA columns.

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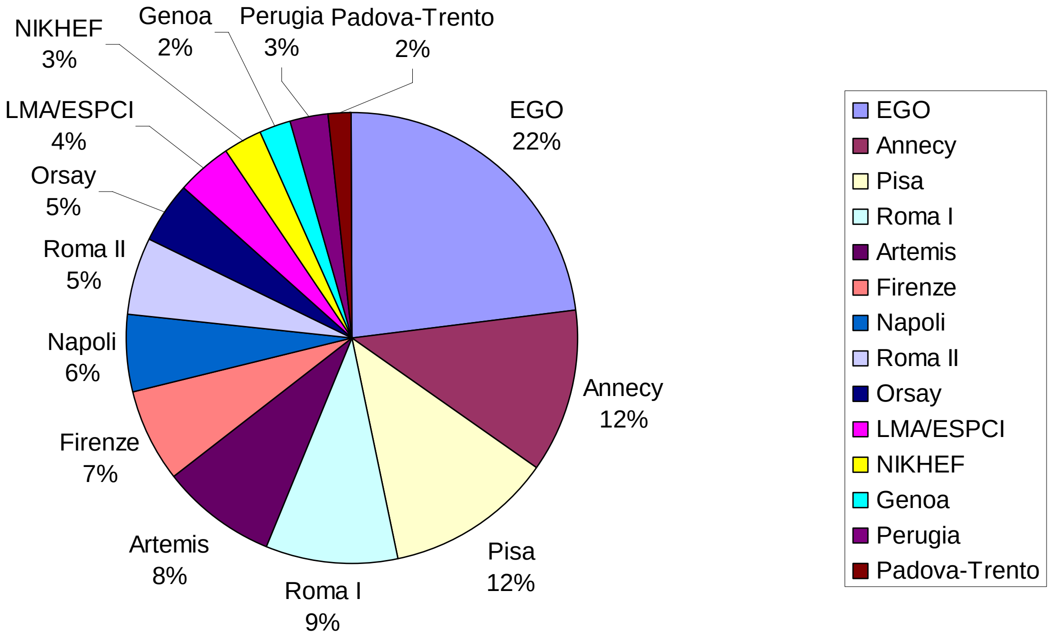

Figure 33 Graphical representation of the FTE contribution to VIRGO. The University persons are assumed to provide a 75% FTE for research time in this chart.

Group	Persons	FTP	Student	Authors	FTE	V	V+	AdV	DA	Other
Annecy	18	11	0	12	14,8	3,2	8,2	0,3	3,3	0,0
Artemis	14	5	2	12	10,2	1,4	2,8	3,0	3,0	0,0
Firenze	10	6	2	10	9,4	1,9	1,7	3,8	2,0	0,8
Genoa	8	0	1	3	2,8	0,5	0,8	1,5	0,0	0,0
LMA/ESPCI	12	0	1	8	4,6	0,4	2,5	1,7	0,1	0,0
Napoli	15	1	4	10	7,9	2,1	0,1	3,1	2,6	2,2
NIKHEF	7	0	1	4	4,0	0,6	1,6	0,0	1,9	0,0
Orsay	7	5	0	8	6,0	0,7	0,0	1,6	3,7	0,0
Padova-Trento	4	0	0	4	2,0	0,2	0,0	0,0	1,8	0,0
Perugia	10	2	2	9	3,5	0,5	1,0	1,1	1,0	3,4
Pisa	24	6	7	22	14,7	2,6	2,5	4,2	5,4	4,6
Roma I	16	7	2	9	12,1	1,1	2,8	3,1	5,1	0,0
Roma II	10	0	2	8	6,8	0,0	2,8	2,2	1,8	0,0
Total	**155**	**43**	**24**	**119**	**98,8**	**15,1**	**26,7**	**25,5**	**31,7**	**11,0**
EGO	32	25	0	21	28,1	18,1	6,2	1,9	1,9	
Total	**187**	**68**	**24**	**140**	**126,9**	**33,2**	**32,9**	**27,4**	**33,6**	**11,0**

Table made without any teaching duty.

The following table gives the breakdown of the contributions to the different data analysis working groups. Notice that some persons who are working on the data analysis are also working on other hardware activities. :

Topic	# of persons	FTE
Coalescing Binaries	9	4.8
Bursts	19	11.2
Periodic	12	6.2
Stochastic	5	2.4
Noise, Data transfer, support	18	7.1

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