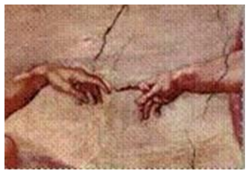
ASPERA Common Call

ET R&D

Networking and R&D for the Einstein Telescope



Meeting Minutes

WP1	WP2	WP3	WP4	MC	GM	Other
				X		

Title of the Meeting:	Management Committee Meeting, Telecon,
hyperlink:	
Date:	17/10/2014
Location (or phone)	phone

Participants			
01	Harald Lück (author of the notes)	02	Andreas Freise
03	Ronny Nawrodt	04	Stuart Reid
05	Iain Martin	06	Tomasz Bulik
07	Michele Punturo	08	
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Agenda

- status of the work in the WGs
- news from individual partners
- date for next meeting
- AOB

With 7 out of 11 members of the ET R&D MC participating in the meeting the required threshold of 3/5 according to our MOU had been (just) reached, making this a valid MC meeting of which we agreed to have at least four per year.

Harald Lück reported that the preparation of the ASPERA/APPEC mid term report is under way. Contributions from WG1 and WG4 have been sent to Harald, who is condensing this into a publishable summary requested by ASPERA/APPEC. The first draft of the summary was presented, discussed and the existing part approved.

With Jo v.d. Brand being on holidays, Thomasz Bulik reported on progress in WG2: a set of two sensors, consisting of commercial Geophones has been set up, tested and calibrated. Currently a new set with 2.5 Hz geophones is being produces, which should reach suffieicent sensitivity to measure seismic background in an underground location down to 1 Hz. After successful testing production of a larger set will start. No long term measurements have yet been performed, but rapid completion of the sensor production should still allow gathering a full year of data at various sites.
Jo will send his report in about a week's time after he returned from holidays.

Ronny Nawrodt reported on the status of WG3:
Three independent and different set-ups have been realized for the measurement of birefringence. The room temperature values measured so far agree with values that can be found in the literature for similar samples. The next step is to perform cryogenic measurements and obtain values for birefringence and absorption. The spatial distribution of the optical absorption of silicon has been measured in Glasgow for different samples. Electrical properties have been investigated in Jena. The Russian group working in WG3 is preparing their set-up to do cryogenic measurements.

The current draft status of the report is appended to theses minutes and summarizes the status of WG1 and WG4. Andreas Freise reported on the status of WG4. The pure simulation tasks may be slightly behind schedule as the overhead in preparing all the required tools had been underestimated.

- There were no news reported from individual partners
- the next meeting will be held during the general ET meeting in Lyon at Nov. 19,20

Current draft of mid term report:

REPORTING TEMPLATE FOR ASPERA COMMON CALL PROJECTS

Please tick the appropriate box: first year: ☒ Final Report: ☐

Period covered: From 1.3.2013 to 31.8.2014

Date of submission: / / (includes first 18 months of project)

1. PROJECT AND PARTICIPANT DETAILS:

Project Acronym: ET R&D

Project Name: ET-R&D – Networking and R&D for the Einstein Telescope

Project website: http://www.et-gw.eu/

PROJECT COORDINATOR:

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OTHER PROJECT PARTNERS (FUNDED VIA THE ASPERA CALL)

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Partner 7:
Organisation: the Russian Einstein Telescope Consortium consisting of the Sternberg Astronomical Institute of the Lomonosov Moscow State University (SAI MSU), the Physics Department of Lomonosov Moscow

State University (Phys.Dept. MSU), the Institute of Nuclear Research of Russian Academy of Science (INR RAS), the Baksan Neutrino Observatory of Russian Academy of Science (BNO INR RAS)

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Partner 8:
Organisation: The Polish Einstein Telescope Consortium, consisting of the University of Warsaw, the University of Białystok, the University of Zielona Gora, the Warsaw Technical University, the Institute of Mathematics of the Polish academy of Sciences, and the Nicoalus Copernicus Astronomical Center of the Polish Academy of Sciences,Country: Russia

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ASSOCIATED PARTNERS (FUNDED ELSEWHERE)

Associated Partner 1:
Organisation: The Hungarian Einstein Telescope Consortium, consisting of the Wigner Research Center for Physics of the Hungarian Academy of Sciences in Budapest, the Geodetic and Geophysical Institute of the Research Centre for Astronomy and Earth Sciences of the Hungarian Academy of Sciences in Sopron and the University of Miskolc

Contact person

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Associated Partner 2:
Organisation: The Italian Einstein Telescope Collaboration, consisting of the following scientists and institutions

Name	Institution
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Barone, Fabrizio	Medicine and Surgery Department University of Salerno, INFN Napoli
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De Rosa, Rosario	Physics Department University of Napoli Federico II, INFN Napoli
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Romano, Rocco	Pharmacy Department University of Salerno, INFN Napoli
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Bradaschia, Carlo	EGO, INFN Pisa
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Frasca, Sergio	Dipartimento di Fisica, Università la Sapienza
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2. PUBLISHABLE SUMMARY

The project **ET R&D** addresses long lead time R&D aspects of the third generation gravitational wave (GW) observatory called Einstein Telescope (ET), a pan-European research infrastructure to be inserted into the ESFRI roadmap with the goal of routine GW astronomy. ET is a planned large, underground infrastructure for hosting several interferometric GW detectors with a sensitivity level surpassing the currently built generation by a factor of about ten. The four scientific working groups of the project are investigating the Science potential of ET, studying underground long term seismic noise to provide scientific site selection criteria, measuring the optical properties of silicon at cryogenic temperatures and do simulations of control aspects that are specific to the technology and arrangement of ET.

In an analysis of three different sets of synthesized GW data, with signals from different sets of sources, embedded in noise as it would be expected from ET it was tested how well the computer codes developed can retrieve these signals and what scientific conclusions can be drawn from the observations. Numerical values for the accuracy of testing General Relativity in the strong field case, i.e. in the vicinity of black holes could be derived. GWs emitted from coalescing binary neutron star systems can be used to determine the cosmological redshift with ET without the need of an electromagnetic counterpart. Key physical factors that shape the population of very massive double black-hole binaries have been identified and from the statistics of the observation (or lack of) the GWs emitted in their coalescence important constraints on the formation and evolution of very massive stars can be derived.

ET will require cryogenic optics and Silicon is a good candidate identified in a conceptual design study. Optical absorption at a wavelength of 1550nm could be shown to be as low as 4 ppm/cm in ultra-pure samples, and first steps understanding absorption mechanisms have been taken. Measurements of intrinsic birefringence showered encouraging values. First measurements of stress induced birefringence have been made, which roughly agree with values mentioned in the literature for different conditions.

Control aspects of ET have been addressed in analytical and numerical simulations which have now been upgraded to also include radiation pressure effects, quantum noise and new features for the analysis of beam shape distortions.

3. WORK PROGRESS AND ACHIEVEMENTS DURING THE PERIOD

A short description of the work progress and achievements (this should cover the ASPERA-funded activities, but please set this in the context of the whole R&D project).
a. Please include: overall progress, developments in the collaboration (e.g. new partners), progress in securing other funding, important results and their significance to the field. If this is the final report, please list the major objectives of the project and describe whether these have been achieved. (Max one page A4)

WORK PACKAGE 1

ET’S SCIENCE POTENTIAL

In the reporting period there has been quite a lot progress on all tasks of WP1 as discussed below. Several papers have either been published or submitted for publication.

Task 1: Mock ET data and science challenges: After the success of the first mock data challenge, we extended our data generation package and produced three new sets of data. The first one contains all types of stellar compact binary coalescences composed of two neutron stars, a black hole and a neutron star or two black holes. The second data set contains the population of CBC too faint to be detected individually but creates a residual GW background. The third data set contains the same population of CBC as ET the second data set but also two supernovae burst signals and two f-modes, and also a population of intermediate-mass black hole binary coalescences and intermediate mass ratio inspiral. Analysis of the mock data set looking for stochastic background has now concluded and a paper has been submitted for publication. Assuming that the loudest sources can be detected individually and removed from the data, we have shown that the residual background can be recovered with an accuracy of 1% with the standard cross-correlation statistic, after correction of a systematic bias due to the non-isotropic distribution of the non-detected population of sources.

We have run Bayesian inference tests on burst injections and extended existing infrastructure to perform parameter estimation of supernova signals. Search for intermediate mass binary black holes and intermediate mass ratio inspirals are on going as also a search for long duration compact binary coalescences using a new pipeline called GSTLAL.

Task 2: Astrophysical models of GW sources: ET can provide important constraints on the formation and evolution of very massive stars. Binaries of two ~ 100 $M_\odot$ black holes would be detectable to redshifts of z ~5-7 with ET. Current models predict that when stars of this mass leave the main sequence, their expansion is insufficient to allow common envelope evolution to efficiently reduce the orbital separation. The resulting binary black hole remains too wide to be able to coalesce within a Hubble time. If this assessment is correct, isolated very massive binaries do not evolve to be gravitational-wave sources. However, the high multiplicity of massive stars, and their common formation in relatively dense stellar associations, opens up dynamical channels for massive black hole mergers. We identify key physical factors that shape the population of very massive double black-hole binaries.

We have studied the coincident rate of binary systems composed of two neutron stars or a neutron star and a black hole and show that the fraction of GW triggers that can be observed in coincidence with short-hard gamma-ray bursts (SGRB) is directly related to the beaming factor at z=0, but increases with distance, until it reaches 100% at the GW horizon distance. When this is taken into account the coincident GW-SGRB rate is improved by a factor of ~3 compared to the simple beaming factor correction. We provide an estimate of the performance future SGRB detectors should achieve in order to fully exploit the potentiality of ET, and we propose a simple method to constrain the beaming angle of SGRBs.

Task 3: Strong field tests of GR with ET: ET would enable tests of the no-hair theorem by looking at the characteristic frequencies and damping times of black hole ringdown signals. In previous work it was shown that with a single 500–1000 $M_\odot$ black hole at a distance $\lesssim$ 6 Gpc (or redshift $z \lesssim 1$), deviations of a few percent in the frequencies and damping times of dominant and subdominant modes would be within the range of detectability. We employed a new model-selection scheme called TIGER to explore how well the no-hair theorem can be tested with a population of black hole ringdown signals observed in ET. By performing a range of simulations using the expected noise power spectral density of ET, we find that with TIGER, similar deviations from the no-hair theorem will be detectable with great confidence using approximately 10 sources distributed uniformly in a comoving volume out to 50 Gpc ($z \lesssim 5$).

We have compared an approximate method that was proposed to compute Bayes factor used in testing general relativity with the exact (but computationally expensive) method. The approximate scheme is based on two easy-to-compute quantities: the signal-to-noise ratio of the event and the fitting factor between the signal and the manifold of possible waveforms within general relativity. We compare the prediction from the approximate formula against an exact numerical calculation of the Bayes factor and find that the approximate scheme predicts exact results with good accuracy, providing the correct scaling with the signal-to-noise ratio at a fitting factor value of 0.992 and the correct scaling with the fitting factor at a signal-to-noise ratio of 20, down to a fitting factor of ~ 0.9. We extend the framework for the approximate calculation of the Bayes factor to fitting factors of ~ 0.7 or higher.

Task 4: Probe ET's potential for understanding the geometry and dynamics of the Universe: It is well known that inspiral signals from coalescing binaries can be used to infer the luminosity distance to the source without the need for any cosmic distance ladder. However, it was thought until recently that is not possible to measure the cosmological redshift of a host galaxy from gravitational wave observations. We have shown that by using the spectrum of a binary neutron star signal in the merger phase it will be possible do measure the redshift. In order for this technique to work it is necessary to have accurate models of the waveform emitted by a neutron star binary. Future research in this area will focus on obtaining such waveform models, which would also be useful in measuring the neutron star equation of state.

Publications:

1. *Testing the no-hair theorem with black hole ringdowns using TIGER,* J. Meidam, M. Agathos, C. Van Den Broeck, J. Veitch, B.S. Sathyaprakash*,* Phys. Rev. D **90**, 064009 (2014)
2. Astrophysics, cosmology, and fundamental physics with compact binary coalescence and the Einstein Telescope, C. Van Den Broeck, J. Phys. Conf. Ser. **484**, 012008 (2014)
3. Measuring neutron-star ellipticity with measurements of the stochastic gravitational-wave background, D. Talukder, E. Thrane, S. Bose, T. Regimbau, Phys. Rev. D **89** (2014) 123008.
4. *Source redshifts from gravitational-wave observations of binary neutron star mergers*, C. Messenger, K. Takami, S. Gossan, L. Rezzolla, B. Sathyaprakash, Phys. Rev. X **4**, 041004 (2014).
5. Systematic Parameter Errors in Inspiraling Neutron Star Binaries, M. Favata, Phys. Rev. Lett. **112**, 101101 (2014).
6. *Revisiting coincidence rate between Gravitational Wave detection and short Gamma-Ray Burst for the Advanced and third generation*, T. Regimbau, K. Siellez, D. Meacher, B. Gendre, M. Bo¨er, Accepted for publication in Astrophysical Journal.
7. *Testing general relativity with compact coalescing binaries: comparing exact and predictive methods to compute the Bayes factor,* W. Del Pozzo, K. Grover, I. Mandel, A. Vecchio, arXiv:1408.2356v1 [gr-qc].
8. *Second Einstein Telescope Mock Science Challenge: Detection of the GW Stochastic Background from Compact Binary Coalescences,* T. Regimbau and D. Meacher, M. Coughlin, arXiv:1404.1134v1 [astro-ph.CO]
9. *The formation and gravitational-wave detection of massive stellar black-hole binaries*, K. Belczynski, A. Buonanno, M. Cantiello, C.L. Fryer, D.E. Holz, I. Mandel, M.C. Miller, M. Walczak, arXiv:1403.0677v3 [astro-ph.HE]

WORK PACKAGE 3

OPTICAL PROPERTIES OF SILICON AT CRYOGENIC TEMPERATURES

WORK PACKAGE 4

ET CONTROL SYSTEMS

The aim this work package is to investigate the control aspects of the current conceptual design of the ET interferometers [1], in particular regarding a) the feasibility to achieve and maintain a stable operation and b) methods for mitigating noise. Numerical interferometer simulations provide the means to create in-silico models on future detectors such as ET, and to quickly explore alternative interferometric designs or new concepts. Daniel Brown and Andreas Freise (Birmingham) have published a major release of the software FINESSE [1], adding new features for the analysis of beam shape distortions, radiation pressure effects and quantum noise. With this upgrade FINESSE has become a key tool for performing correct simulations of ET interferometers. The software is further developed in order to reduce the computation time, especially for simulations of parametric instabilities In realistic setups.

Vaishali Adya (AEI-Hannover) and Sean Leavey (Glasgow) have built models using two interferometer simulation packages (Optickle and FINESSE) towards the design of a feasible control scheme for the low-frequency interferometer (ET-LF). Progressive developments of the model are being produced, optimising the different macroscopic lengths and modulation frequencies. The current models were used to show a first control scheme capable of separating the interferometeric degrees of freedom. Further optimisations are on-going. The next key milestone will be the ability to compute noise budgets for comparing different options for ET-LF control schemes.

Nikita Vostrosablin and Sergey Vyatchanin (Moscow State University) have performed theoretical investigations into optical rigidity, whose understand is crucial both for mitigating stability issues of parametric instabilities and for implementing new concepts to shape the interferometer response through optical springs. We explored the possibility to stabilise optical springs in an Advanced LIGO setup and could show that a stable optical spring may be also obtained in Michelson-Sagnac interferometer with both power and signal recycling mirrors and unbalanced arms [3].

Our work is closely linked to the wider research effort in the international gravitational wave community into the development of new technologies for future detectors. For example, Stefan Hild (Glasgow) has continued to lead a team for developing design ideas for upgrades to the Advanced LIGO detectors [4]. Intimately linked to the topic of interferometer control is the research into the fundamental noise limiting future interferometers. Members of this working group have for example contributed by investigating an alternative quantum noise reduction scheme [5], and by determining the thermal noise in interferometers with folded cavities [6].

[1] C. Graef: “Towards ET Control”, 5th Annual ET Symposium, Hannover, Germany, October 2013

[2] FINESSE 2.0, Project page http://www.gwoptics.org/finesse/, public release May 2014

[3] N.A. Vostrosablin and S.P. Vyatchanin, Stable optical spring in aLIGO detector with unbalanced arms and in Michelson-Sagnac interferometer, Physical Review D **89**, 062005 (2014)

[4] B. Barr *et al.* : ‘LIGO 3 Strawman Design, Team Red’, LIGO technical note, T1200005 (2012)

[5] M. Wang, H. Miao, A. Freise and Y. Chen: ‘Sensitivity of intracavity filtering schemes for detec- ting gravitational waves’, Phys. Rev. D 89, 062009 (2014)

[6] D. Heinert, K. Craig, H. Grote, S. Hild, H. Lück, R. Nawrodt, D.A. Simakov, D.V. Vasilyev, S.P. Vyatchanin and H. Wittel, Thermal noise of folding mirrors, Physical Review D **90**, 042001 (2014)

- A memorandum of Understanding has been set up, finally agreed on and signed by all contributing partners. The associated French colleagues, who participate in the project actively, e.g. in optical absorption experiments of silicon samples, have not formally joined the project by signing the MOU, but are represented in the management Council by a French advisor.
- Regular teleconferences were held within the individual working groups to coordinate work and progress. The ET R&D Management Council held 3 teleconferences. General teleconferences with participation of many members of the project were initially held at about monthly rates, but was considered too frequent. It was decided to hold the general meetings together with the ELiTES project teleconferences. No such general meeting have been held since then. Instead joint working group meeting where there is overlap between the ET R&D working groups and ELiTES have been held.
- A general Einstein Telescope meeting with 79 participants (http://et-meeting2013.aei.mpg.de/) was held in Hannover in Germany October 22 and 23, 2013. The next general Einstein telescope meeting will be held in Lyon on November 19,20, 2014.
- A webpage for the ET R&D project has been created in the framework of the Einstein Telescope web pages (http://www.et-gw.eu/)
- Results, reports and publications are stored in a centralized data base (https://tds.ego-gw.it/itf/tds/index.php) administered by the associated partner EGO.

4. MILESTONES AND DELIVERABLES.

Please indicate whether the planned ASPERA-funded deliverables and milestones have been completed, delayed or readjusted (in the progress column).

MILESTONES

Milestone	Partners responsible	Original Completion Date	Actual/Estimated Completion Date	Progress	Comments
MS 5.1	all	M1	M1	completed	
MS 3.1	Glasgow, LUH-AEI, FSU	M7	M7	completed	
MS 2.1		M9			
MS 1.1		M12			
MS 3.2	FSU, LUH-AEI	M15	M15	completed	further investigations triggered (surface absorption)
MS 1.2		M18			
MS 3.3	LUH-AEI	M18	M18	completed	
MS 3.4	LUH-AEI, Glasgow, FSU	M18	M15	completed	three complementary setups developed
MS 4.1		M19			
MS 2.2		M20			
MS 3.5	FSU	M22	M21	completed	
MS 4.2		M25			
MS 3.6		M25			
MS 1.3		M33			
MS 2.3		M34			
MS 3.7		M36			
MS 3.8		M36			
MS 4.3		M36			
MS 3.9		M36			
MS 4.4		M36			
MS 4.5		M36			

DELIVERABLES

Deliverable/WP	Partners responsible	Original Completion Date	Actual/Estimated Completion Date	Progress	Comments
D 1.1	UNICARDIFF, NIKHEF, Polish and Russian ET Consortium, UNIGLASGOW	M12			
D 2.1	NIKHEF, Polish and Russian ET Consortium	M12			
D 3.1	FSU, LUH-AEI, UNIGLASGOW, Russian ET Consortium, UWS	M12			
D 4.1	UNIBHAM, UNIGLASGOW, Russian ET Consortium	M12			
D 5.1	LUH-AEI, all	M12			
D 1.2	UNICARDIFF, NIKHEF, Polish and Russian ET Consortium, UNIGLASGOW	M24			
D 2.2	NIKHEF, Polish and Russian ET Consortium	M24			
D 3.2	FSU, LUH-AEI, UNIGLASGOW,	M24			

	Russian ET Consortium, UWS				
D 4.2	UNIBHAM, UNIGLASGOW, Russian ET Consortium	M24			
D 5.2	LUH-AEI, all	M24			
D 1.3	UNICARDIFF, NIKHEF, Polish and Russian ET Consortium, UNIGLASGOW	M36			
D 2.3	NIKHEF, Polish and Russian ET Consortium	M36			
D 3.3	FSU, LUH-AEI, UNIGLASGOW, Russian ET Consortium, UWS	M36			
D 4.3	UNIBHAM, UNIGLASGOW, Russian ET Consortium	M36			
D 5.3	LUH-AEI, all	M36			
D 5.4	LUH-AEI, all	M36			

5. PROJECT MANAGEMENT

Please summarize the activities related to the management of the ASPERA-funded project only ***(max 1 page A4),*** *including finances (see table below), structures, processes and meetings that have been put or taken place.*

6. DEVIATIONS FROM ASPERA PROPOSAL/WORKPLAN

Please list and describe any deviations from the project/workplan described in the original ASPERA call proposal, as a result of the final funding awarded or other issues.

7. PUBLICATIONS AND DISSEMINATION

*Please provide a list of publications published or in press (**this should cover the ASPERA-funded activities only**)..*

S. Kroker, R. Nawrodt, *The Einstein Telescope*, Metrology for Aerospace (MetroAeroSpace), 2014 IEEE.

D. Heinert, K. Craig, H. Grote, S. Hild, H. Lück, R. Nawrodt, D. A. Simakov, D. V. Vasilyev, S. P. Vyatchanin, H. Wittel, *Thermal noise of folding mirrors*, Phys. Rev. D **90** (2014) 042001.

J. Degallaix, J. Komma, D. Forest, G. Hofmann, M. Granata, D. Heinert, C. Schwarz, R. Nawrodt, L. Pinard, C. Michel, R. Flaminio, G. Cagnoli, *Measurement of the optical absorption of bulk silicon at cryogenic temperature and the implication for the Einstein Telescope*, Class. Quantum Grav. **31** (2014) 185010.

D. Heinert, A. Bell, G. Cagnoli, J. Degallaix, G. Gemme, S. Hild, J. Hough, Y. Levin, H. Lück, I. W. Martin, S. Rowan, S. P. Vyatchanin, R. Nawrodt, *Free carrier driven noise in transmissive semiconductor optics*, submitted to Phys. Rev. Lett. (05/09/2014)

*Please list any **ASPERA-funded** dissemination or outreach activities undertaken during the reporting period (**Max half a page A4**).*

8. ADDED VALUE OF THE ASPERA COMMON CALL

*Please summarize what has been the added value of the ASPERA Common Call to your field and your community (**Max one page A4**).*