A historical perspective on the 3rd generation GW detectors: the early attempts for a joint European effort (1986-1990)

Adele La Rana
INFN Virgo - University of Rome Sapienza
Centro Fermi & TERA Foundation

GEMMA Workshop, Lecce – June 4-7, 2018

Why is there **in Europe only one long-based interferometer** for GW detection instead of two, as in USA?

Can we learn something from the history of European GW research that can help the present European collaborations in order to plan the future 3rd Generation (**3G**) interfometers, as Einstein Telescope?

First-hand data sourcese and oral testimonies

- **Personal folders of:**

Alain Brillet
Adalberto Giazotto
Marco Napolitano

- **Archives:**

Virgo Archive in Cascina
Edoardo Amaldi Archive in Rome

- **Interviews:**

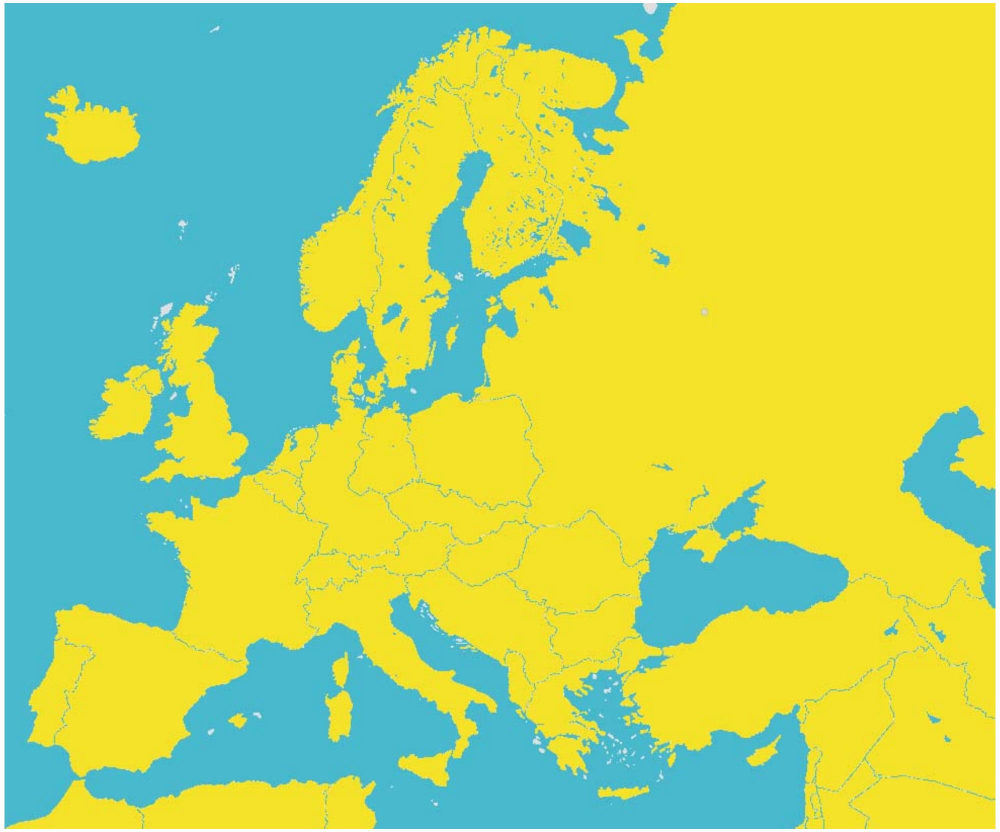
Adalberto Giazotto
Alain Brillet
Albrecht Rudiger
Angela Di Virgilio
Barry Barish
Bernard Schutz
Carlo Bradaschia
David Shoemaker
Diego Passuello
Enrico Calloni
Fulvio Ricci
Gerd Leuchs
Gian Vittorio Pallottino
Giovanni Lo Surdo
Guido Pizzella
Heinrich Heitman
Ian Corbett
Ivo Modena
Jean Yves Vinet
Jim Hough
Leopoldo Milano
Luciano Di Fiore
Marco Napolitano
Paolo Strolin
Walter Winkler

Report on the future of Interferometric Wave Antennas in Europe, March 1988

"A network of three antennas has such a large advantage over only two antennas that it must be a reasonable European goal to build three detectors

Such a network would be capable of providing extremely useful scientific information on its own, regardless of what happens in the world."

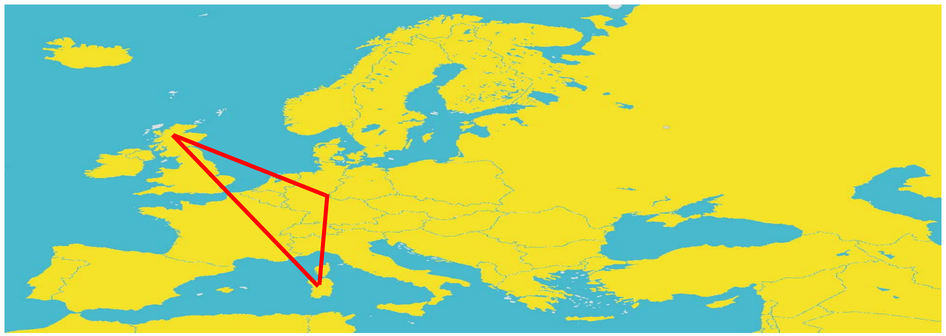
Report of an ad-hoc Working group on the future of Interferometric Wave Antennas in Europe, March 1988



"The European groups […] agreed to form a collaboration, **EUROGRAV**.

All members of the collaboration will work towards establishing the best possible European network, with the aim of establishing a gravitational astronomy."

Report of an ad-hoc Working group on the future of Interferometric Wave Antennas in Europe, March 1988



Membership of Working group:

Alain Brillet CNRS – Univ. Pierre et Marie Curie, Paris

Ian Corbett Rutherford Appleton Laboratory

Adalberto Giazotto INFN section of Pisa and Univ. of Pisa

Jim Hough Univ. of Glasgow

Gerd Leuchs MPI fur Quantenoptik, Garching

Bernard Schutz Univ. College, Cardiff

Philippe Tourrenc CNRS - Univ. Pierre et Marie Curie, Paris

Walter Winkler MPI fur Quantenoptik, Garching

“The European funding bodies are invited to endorse the formation of a collaborative European programme directed towards construction of a network of detectors, and dicuss how the best objectives of that programme can be realized in order that European science can capitalize on its past investment and present scientific and technological lead.”

Report of an ad-hoc Working group on the future of Interferometric Wave Antennas in Europe, March 1988

Funding Agencies involved so far:

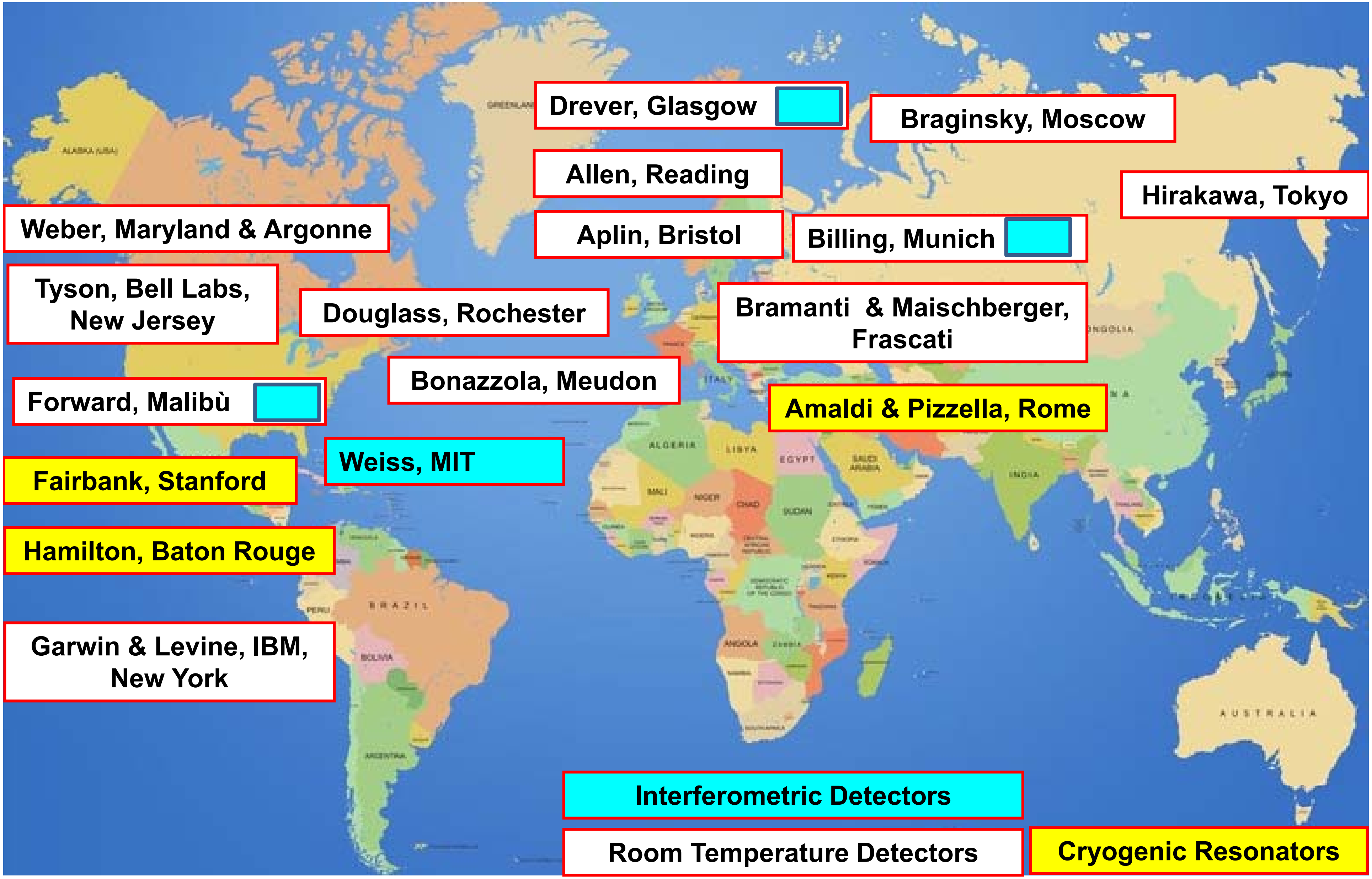
United Kingdom: SERC (Science and Engineering Research Council)

Germany: BMFS (Federal Ministry of Education and Research)

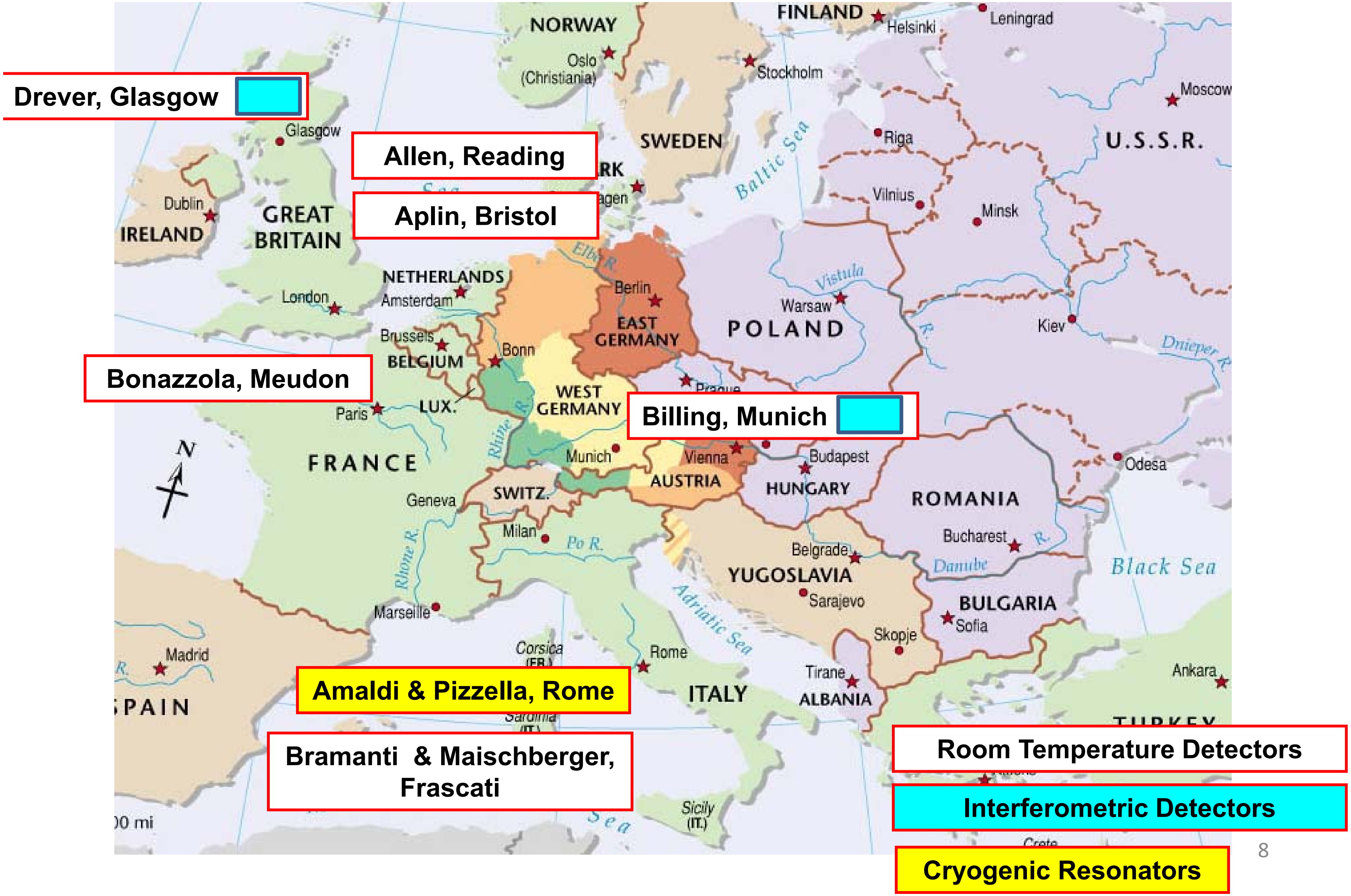
France: CNRS (Centre National de la Recherche Scientifique)

Italy: INFN (Istituto Nazionale di Fisica Nucleare)

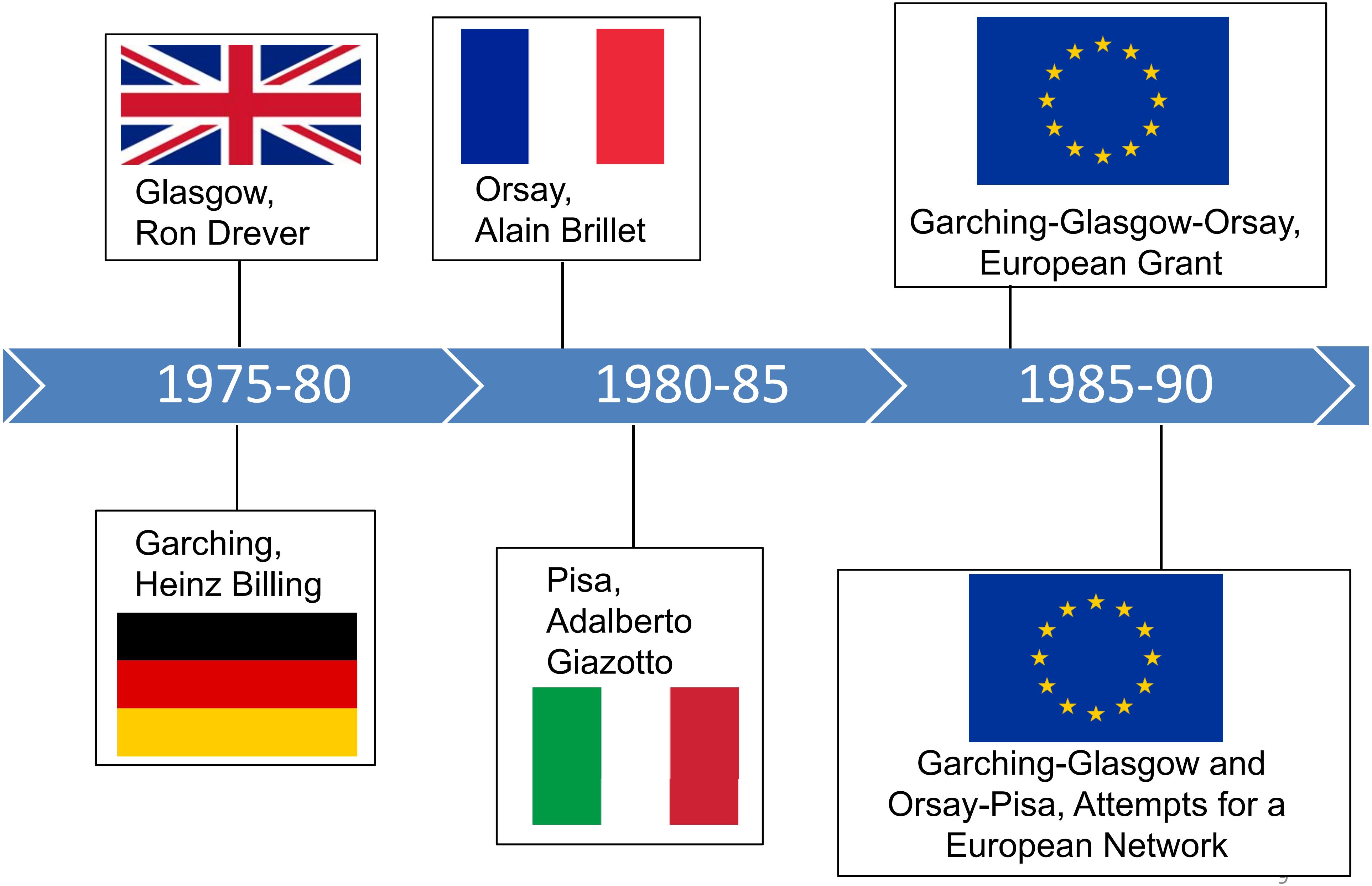
1970-1975: a picture of GW detection in the World



1970-1975: a picture of GW detection in Europe



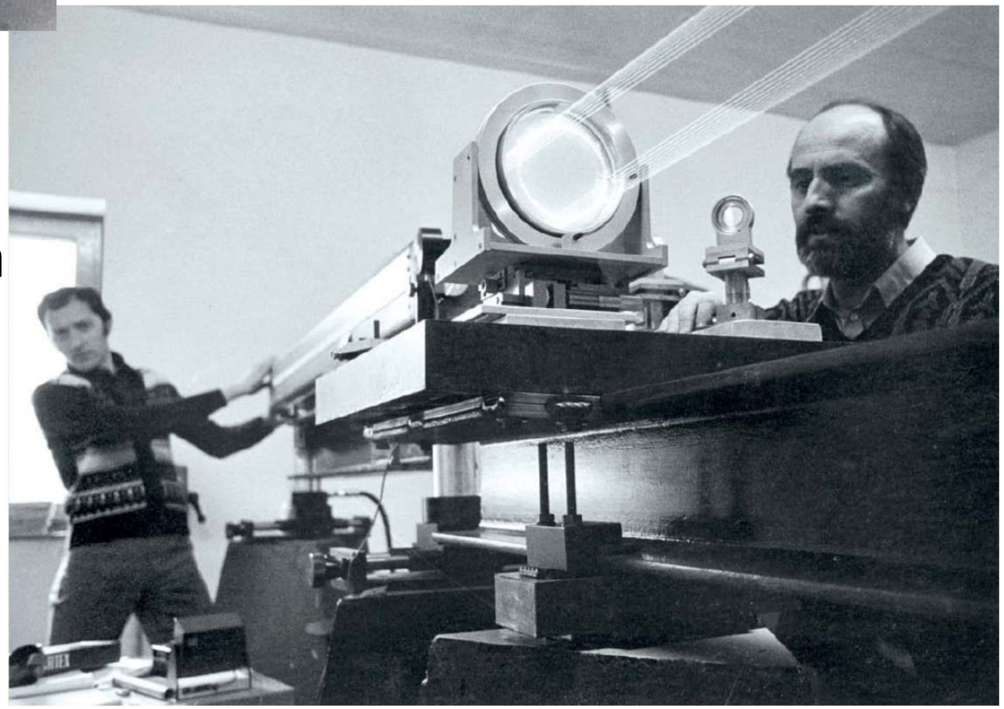
The Start of Interferometric Detector Research in Europe



Heinz Billing, Munich, ‘70s

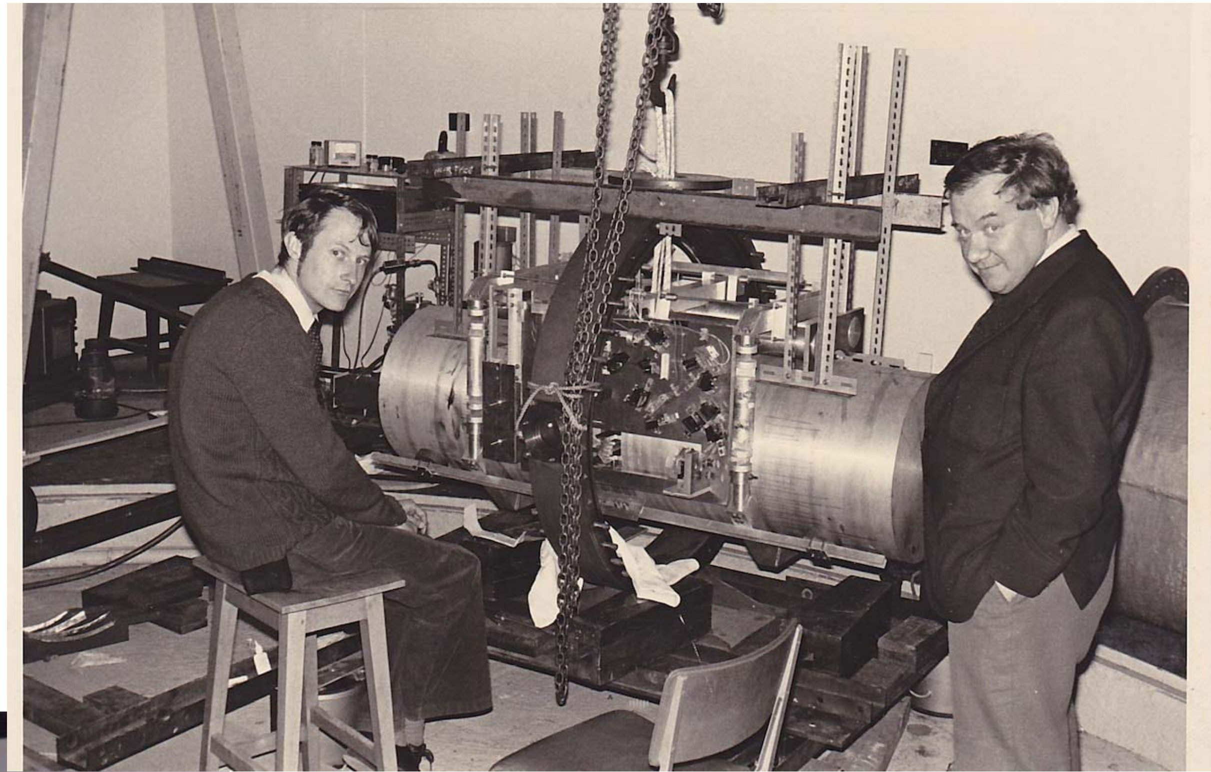
Around 1975 the **Garching group** started to work at developing Rainer Weiss’s ideas on interferometric detection, building a 3 m prototype and being the **first to reach the shot noise limit**.

By 1985, they were operating a **30 m delay line interferometer**, achieving again the shot noise limit, now corresponding to a 10 times lower strain noise (accordingly to the 10 times larger armlength).

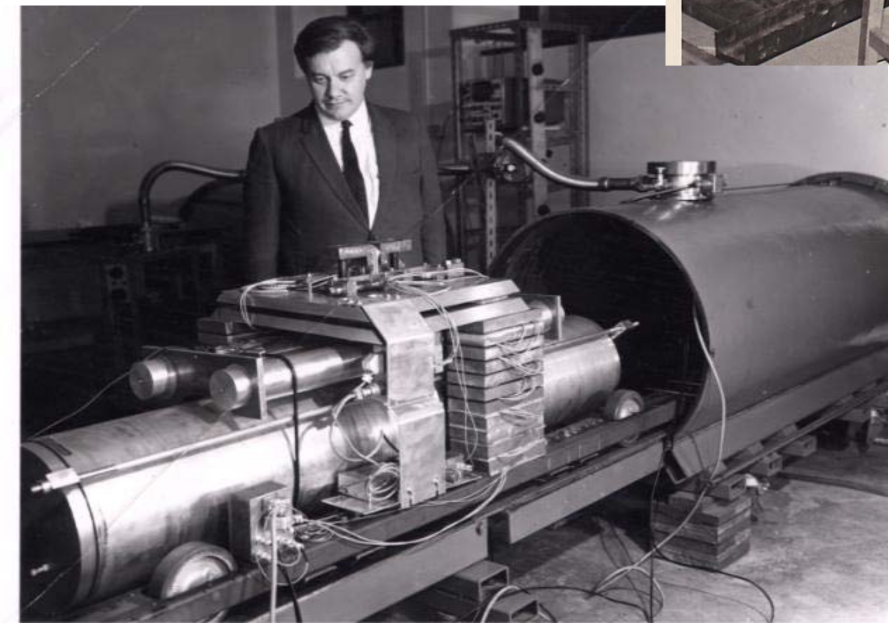


Walter Winkler and Karl Maischberger, Garching, 70s

The **Glasgow team** had begun research activity on bar detectors in the early 70s and migrated to interferometric techniques at about the same time as Garching (around 1975).



Jim Hough and Ron Drever, Glasgow 1972



Ron Drever, Glasgow early 70s

During the 80s the group developing a **10 m prototype** with performance comparable to Garching's, but testing the use of **Fabry-Perot cavities** instead of the delay lines.
First idea of recycling (Drever, 1982).

- **1978:** While a post-doc in Boulder with John Hall, **Brillet** gets interested in interferometric detectors talking with **Peter Bender**, who was designing LISA

- **1979**, Trieste-Marcel Grossmann Meeting: Alain Brillet meets Ron **Drever** and A. **Rüdiger** e R. **Schilling**, presenting first results from their interferometric prototypes.

- **1980-82:** The activity in Orsay on interferometric detectors begins: **Alain Brillet, Jean Yves Vinet** and **Nary Man**, later joined by **David Shoemaker**.

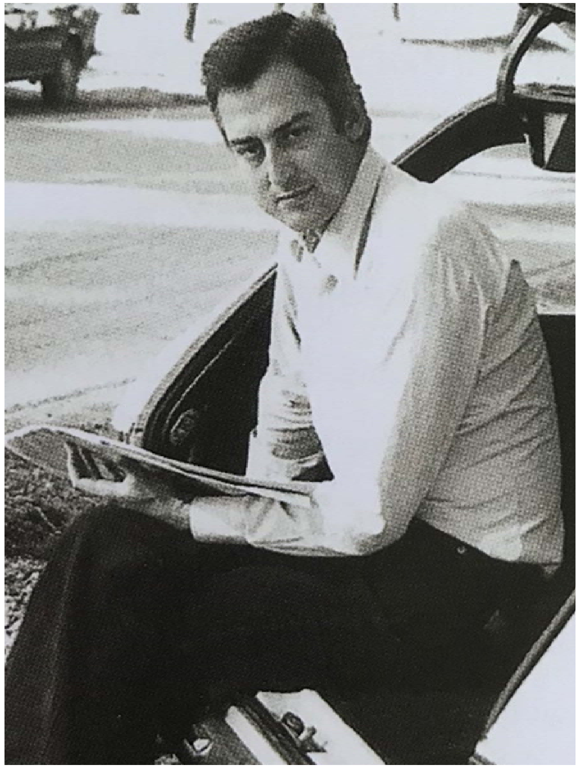
Experimental work on lasers and interferometriques techniques: **Brillet** and **Nary Man**, later **Shoemaker**

Theory of recycling (idea first proposed by Drever in 1982): **Vinet**.

Theoretical models of sources, in Meudon: **Damour**, **Bonazzola**, **Deruelle**, **Carter**

Nary Man, Alain Marraud, Alain Brillet, David Shoemaker, Olivier (student), Sorrento 1988

Towards low frequencies…



Adalberto Giazotto, 70s

- **1982:** A. **Giazotto**, *Interferometric Detection of Gravitational Waves: Theory and Noises,* Internal report, INFN Pisa

- **1984**: A. Giazotto et al., **Interferometer for the Active Reduction of the Seismic Noise**, INFN Proposal

- **Early '80s:** Giazotto begins the **IRAS** activity in San Piero a Grado (Pisa).

Giazotto:
«At that time results from Australian Radiotelescope in Marrabra [ed. *Narrabri*] led by Dick Manchester were giving very exciting results in the Pulsar detection. We realized that a relatively big number of Pulsar could have frequency > 10 Hz»

So what did go wrong?

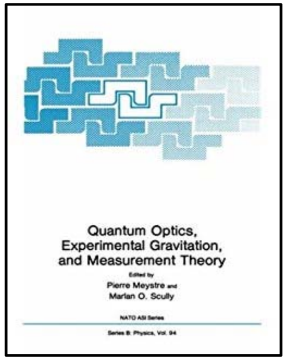
What were the main factors opposing the achievement of a collaboration, which had so strong advantages for everyone?

Why have not the European groups, which were at the time leading the experimental field of GW interferometry, joined forces to build a European GW observatory with at least two detectors of kilometric dimensions in Europe?

Let’s do a step backward, to the start of the contact among the European groups….

Conferences where the GW community met…

- **1979**: Marcel Grossmann Meeting on GR (MG2) **Trieste**. Precision experiments on Gravitation: **Brillet**, **Hall**, *On improved test of the Isotropy of space using laser tehniques*. Brillet meets for the first time Drever and the group of Garching, presenting their first interferometric results.



- **1981**: Conference on Quantum Optics and Experimental General Relativity: **Bad Windsheim** (Germany). Promoted by NATO.

Some of the participants: Wigner, **Wheeler**, **Bordé**, **Brillet**, **Leuchs**, **Thorne**, **Hough**, **Drever**, **Maischberger**, **Braginsky**

- **1984:** Journées Relativistes, May 2-5, **Aussois** (France). Organized by **Philippe Tourrenc**, dir. of Lab. de Physique Théorique, Institut Henri Poincaré (Paris). The Glasgow group first presents its ideas for a large gw interferometer.

- **1985**: Marcel Grossmann Meeting (MG4), **Rome**. Garching group presents: Plans for a large GW antenna in Germany. Brillet meets for the first time Giazotto.

Proceedings of the Fourth
MARCEL GROSSMANN MEETING ON
GENERAL RELATIVITY, R. Ruffini (ed.)

IV Marcel Grossmann Meeting, Roma 1985

PERFORMANCE OF AN ACTIVE PENDULUM WITH INTERFEROMETRIC SENSING

A.GIAZOTTO, E.CAMPANI, D.PASSUELLO and A.STEFANINI

I.N.F.N. Sezione di Pisa and Dipartimento di Fisica, Universita' di Pisa, Pisa,Italy.

We describe the performance of a 100 Kg, 1 m long active pendulum. The pendulum displacement with respect to the suspension point is measured interferometrically. The phase signal, to be sent to the actuator which displaces the pendulum suspension point, is extracted from the interferometer signal using an analog phase follower. At 10 Hz we obtain a virtual pendulum length of 1.6 km. This device can be used to reduce the seismic noise in an antenna for low frequency gravitational wave detection.

The experiment IRAS[1] consists of a pendulum whose suspension point is displaced by means of a piezoelectric transducer (PZT) and of a DC motor. The aim of the experiment is to greatly reduce the seismic noise in the pendulum mass[2,3].

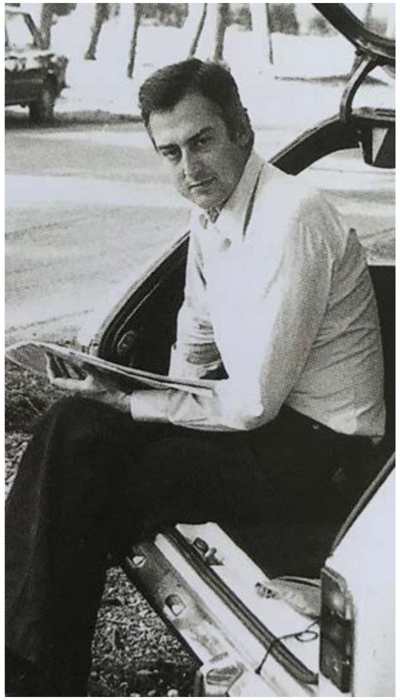
The layout of the experiment is shown in Fig.1.

The pendulum (100 Kg) mass is suspended by two 1.3 m long steel strips .1x.5 mm^2. The transducer PZT1, which can be translated along the X direction by the DC motor (DCM), is placed 30 cm below the suspension point.

<u>The 1985 Garching proposal argues:</u>

“A limitation of the usable frequency range is given at the low-frequency end by the steep increase of many optical and mechanical noise contributions, particularly of the seismic noise. To extend the frequency range to a lower limit of 100 Hz will already be a very difficult task.”
(proposed goal: few hundred of Hz to few kHz)

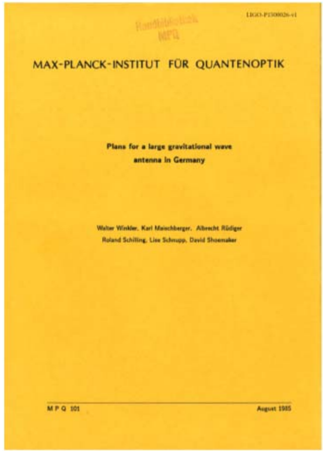
portional to the applied voltage; the total dinamyc phase difference ...



National ambitions

1984: J. Hough, S. Hoggan, G. A. Kerr, J. B. Mougan, B. J. Meers, G. P., Newton, N. A. Robertson, H. Ward, R. W. Drever, ***The development of long-baseline gravitational radiation detectors at Glasgow University***
A detailed design prepared with Rutherford Appleton Lab (**Ian Corbett** et al.) and University College – Cardiff (**B. Shutz**), and proposed to **SERC** in **1986**.

1985, German Proposal:


MAX-PLANCK-INSTITUT FÜR QUANTENOPTIK

Plans for a large gravitational wave antenna in Germany

Walter Winkler, Karl Maischberger, Albrecht Rüdiger
Roland Schilling, Lise Schnupp, David Shoemaker

MPQ 101 August 1985

To guard against spurious signals due to local noises sources, verification with at least one further interferometer is required. […] Collababorations with exp. groups in the other countries is highly desirable.

Brillet:
*De **1982 à 1984**, l'Institut National d'Astrophysique et de Géophysique nous consentit l'aide de ses services techniques pour évaluer le coût d'un détecteur kilométrique sur le site de **Nançay**, et y effectuer des mesures de bruit sismique. En France, le projet avait été placé dès 1986 sur la liste des futurs Très Grands Equipments, mais n'avait pas la priorité, précédé dans le domaine des sciences fondamentales par le VLT.*

First step towards a European network

1985: the groups of Glasgow, Garching and Paris make a joint application for a European twinning grant in the EEC stimulation program, under the impulse of Philippe Tourrenc.

First formal action towards a European collaboration for GW research

CALIFORNIA INSTITUTE OF TECHNOLOGY

GRAVITATIONAL PHYSICS 130-33
PASADENA, CALIFORNIA 91125
(818)-356-4291 & 4098

March 18, 1986

Dr. A. Brillet
Laboratoire de l'Horloge Atomique,
Universite de Paris-Sud,
Centre National De La Recherche Scientifique,
91405 Orsay - Cedex,
FRANCE

Dear Dr. Brillet,

At the meeting on gravitational wave detection by laser interferometry held last month in Cardiff suggestions were made about the potential advantages of arranging some form of international collaboration between the experimental groups working in this field in Europe and the USA, in part to improve the informal contacts and collaboration which are already taking place and benefiting all the groups. We are aware that possibilities for such a collaboration are being discussed in Europe. In the USA, plans for large gravity-wave detection facilities are being made as a joint proposal to the NSF from the Caltech and MIT gravity-wave groups, and the Steering Committee for this joint project has also been considering forms of collaboration.

On behalf of the Caltech/MIT joint gravity wave project we would like to bring to your attention the attached notes outlining one suggestion for a possible form of international collaboration, for which a majority of our Steering Committee has shown a preference. We should be very glad to hear of your opinions about an international collaboration in this field, and any suggestions you may have on the subject.

We feel that a suitable form of international collaboration could benefit our subject greatly in various ways, and we look forward to your suggestions.

We are sending similar letters to Professor H. Walter and Dr. G. Leuchs, Max-Planck-Institute, Garching, and to Dr. J. Hough, University of Glasgow.

We send our best wishes for your own research.

Yours sincerely,
for the joint Caltech/MIT gravity wave project,

R. W. P. Drever

R.W.P. Drever
California Institute
of Technology

R. Weiss
Massachusetts Institute
of Technology

Attachment.
Copy to Dr. R.A. Isaacson, NSF.

March 18, 1986, Drever and Weiss to Brillet:

At the meeting on gw detection by laser interferometry held last month in Cardiff suggestions were made about the potential advantages of arranging some form of international collaboration between the experimental groups working in this field in Europe and the US, in part to improve the informal contacts and collaboration which are already taking place and benefitting all the goups. We are aware that possibilities for such collaboration are being discussed in Europe.

Notes and Suggestions for an International Collaboration on Gravitational Radiation Research using Laser Interferometers

1. Aims of the collaboration

(a) To improve the efficiency and rate of progress of gravitational radiation research using laser interferometers.

(b) To broaden the range of possible experiments in gravitational radiation research by facilitating both collaborative and independent experiments by the groups developing laser interferometer gravitational wave detectors at the University of Glasgow; the Max-Planck Institute, Garching; the CNRS, Orsay; the California Institute of Technology; and the Massachusetts Institute of Technology.

(c) To reduce costs of the research.

(d) To facilitate provision of adequate support in each country by government or other funding agencies.

2. Achievement of these aims

The collaboration will propose and carry out a number of collaborative endeavors. These may include:

(a) Collaboration in coincidence and cross-correlation searches for, and studies of, gravitational waves;

(b) Exchange of information and data on the research;

(c) Collaboration in bulk purchases or manufacture of equipment or components for both collaborative and independent research where this can reduce costs or make special items more widely available;

(d) Collaboration in design and development of particular items of equipment or facilities for both collaborative and independent research.

3

(1) Collaboration on choice and possibly on development of data recording techniques and formats, to reduce costs and simplify data exchange

(2) Collaboration on aspects of data analysis.

Notes from the meeting in Cardiff, attached to Drever's and Weiss' letter to Brillet of March 18, 1986

Istituto Nazionale di Fisica Nucleare

Sezione di Pisa

Pisa, li May 9, 1986

Via Livornese, 582/a - 56010 S. Piero a Grado - Pisa - Italy
Tel. 960013 - 960014 - Telex 500319 PSAFIS I

Prot N.

Codice Fiscale n. 84001850589

Prof. Alain BRILLET
Centre National de la Recherche Scientifique
Laboratoire de L'Horloge Atomique
Batiment 104 - Université de Paris-Sud-91405 ORSAY Cedex

copy to Prof.A.Scribano
Director of the INFN Pisa Section

Prof.E.Flaminio
Pisa Coordinator of the INFN National Scientific Commission II

Dear Alain,

As you well know the IRAS group is now working on an experiment having the aim of reducing the seismic noise in the frequency range 10-150 Hz; the final target is to realize a wide band gravitational antenna able to work also in that frequency range having enough sensitivity to observe the periodic gravitational emission due to the Pulsar. An interferometric antenna with large base line should be the best if the laser noise can be reduced at low frequency.

It should be then very nice if our two groups could collaborate together in view of the common scientific interest and of the complementary knowledges.

As you also mentioned in your letter of 11/4/86 the hope is that we can in the future realize a large interferometric antenna having good sensitivity at low frequency.

It should be very useful if we could start with a feasibility study for this detector. The Pisa-INFN is ready to give due support to a common program presented and approved by the INFN National Scientific Committee.

Yours Sincerely

(Adalberto Giazotto)

May 9, 1986 – Giazotto to Brillet:

It should be then very nice if our two groups could collaborate together in view of the common scientific interest and of the complementary knowledges. As you also mentioned in your letter of 11/4/86 the hope is that we can in the future realize a large interferometric antenna having good sensitivity at low frequency. […]

The Pisa-INFN is ready to give due support to a common program presented and approved by the INFN National Scientific Committee.

12 Mai 86

Dear Dr.Giazotto,

By the present letter, we wish to establish some facts which could be used as a basis for future cooperative work in the field of gravitational waves(G.W.) detection.

The first fact resides in your present achievements and your projects concerning the development of very efficient low frequency seismic isolation devices:this is obviously a very important subject for the future interferometric G.W. antennas.The simple devices which are being realised by the groups at Caltech,Glasgow,München and Orsay will provide adequate isolation only at frequencies larger than a few hundred hertz,while we know that the range of interesting frequencies extends much lower.The M.I.T. group alone has already been able to consider low frequency isolation schemes.

The second fact is that the field of G.W. detection calls for collaborations, for a few different reasons:

-the signals expected are so weak that only coïncidence experiments will ensure their detection.

-the dimensions of the antennas being necessarily small compared with the wavelength,one must use V.L.B.I. techniques involving widely spaced antennas in order to localise the sources and to obtain useful astrophysical informations.

-the size of each of the research groups in the field is too small(5 to 6 persons in the average) to allow any single group to tackle all the problems.Particularly,in Orsay we have decided to concentrate on the lasers stability and power issues and to rely on cooperative actions for solving the other problems.

The third fact is that formal international collaborations are already appearing to which you may wish to participate:

-In 1985,under the impulse of P.Tourreno,the European groups asked for a stimulation grant from the E.E.C..This has been accepted and it will allow the development of YAG lasers in Orsay,the study of high reflectivity mirrors in Glasgow and the organisation of a european workshop in Paris,next December.P.tourreno is also organising a small meeting on May 26th and 27th to prepare the next grant,for which you must have received an invitation already.

-A first draft concerning the establishment of a wider international collaboration has been recently circulated.You will find copies of this draft and of the answer we gave to it attached to the present letter.

Finally we wish to point out that,independently of these wide multinational projects which may stay rather unprecise for a few years,we are ready and willing to discuss with you about the possibility of adding your and our competences for working together on a precise project and even to study the opportunity of building,later,a common antenna.

Yours sincerely,

A.BRILLET

May 12, 1986 – Brillet to Giazotto:

The simple devices which are being realized by the groups at Caltech, Glasgow, Munich and Orsay will provide adequate isolation only at frequencies larger than a few hundred hertz, while we know that the range of interesting frequencies extends much lower.

[…] *formal international collaborations are already appearing, to which you may wish to participate.*

Brillet was referring to the European groups, but also to wider collaboration with MIT and Caltech scientists (Cardiff meeting in February 1986)

EUROPEAN GRAVITATIONAL WAVE DETECTOR WORKING PARTY

The aim of this Working Party is to produce a report to be submitted to the three funding bodies which have so far been approached: BMFT, CNRS and SERC. Neither the Working Party nor its report will have any official status.

The report should present a unanimous view of a collaborative European approach to the construction and operation of interferometric gravitational wave detectors. It should address and offer solutions to technical problems, provide realistic cost envelopes for a limited range of options, and present and evaluate models for the organisation and management of the collaborative project.

To be effective, the working party must produce arguments which convince the funding agencies not only of the importance and timeliness of the science and the technological feasibility of the project, but also of the ability and determination of the separate groups to work together. Its conclusions and recommendations should provide a negotiating framework for the funding agencies, and form the basis of any approach which might be made to other funding bodies, national or European. Any new groups proposing to join the original collaboration would be expected to accept it as the basic working document.

SOME TOPICS TO BE CONSIDERED

1. Whilst we are convinced that there should be at least two detectors in Europe, what are the cogent scientific arguments to justify this? How many antennae should we attempt to argue for?

2. Is there a minimum/optimum separation between antennae?

3. What is the minimum arm length?

4. Can we quantify the trade-offs in length versus number of separate antennae versus number of interferometers in one installation? Can we define and defend a minimum investment? Can we quantify the gains in going from that minimum?

5. Should we ever try to decide between Fabry-Perot and delay line? Can we produce a basic design compatible with both techniques?

6. What are the arguments for building the antennae simultaneously? Do we have the scientific resources to build and commission them simultaneously? What are the arguments against building only one antenna, proving it, and then building the next?

7. How much can be done in common, how much should be done in common, and how much must be done in common?

Ian Corbett, April 24, 1987, to the groups in Glasgow and in Paris.

European GW Detector Working Party, constituted few months before among the optical groups Glasgow, Garching and Orsay.

"The WG must produce arguments which convince the funding agencies not only of the importance and timeliness of the science and technological feasibility of the project, but also of the ability and determination of the separate groups to work together."

European Gravitational Wave Detector Working Party

8. Should we have a common data acquisition, storage and analysis philosophy from the start? Should we have a single European data storage and analysis centre, networked to the sites and to the collaborating institutions? (Some of this will come out of the July Cardiff meeting.)

9. What will the relationship be with other detectors e.g. in the USA? Should there be worldwide standardisation on e.g. protocols and software?

10. How do we organise the collaboration? Do we envisage a single co-ordination and management committee for the whole project comprising several antennae and many interferometers? Should this committee have financial authority delegated by the funding agencies, or should the various national groups contribute in equipment and manpower, under their own control? How do we maintain the integrity of the national groups? How do we minimise bureaucracy while retaining accountability?

11. What existing collaborative projects could provide a useful model? (or, conversely, indicate things to avoid!)

12. What is the long-term role of the two prototype detectors (Garching and Glasgow)? Should the extent of prototype R&D be expanded? When?

13. What should we propose in the future to the European Commission? What is the best way of continuing and extending present EC funded work? What other source(s) of funds could be approached?

24 April 1987

Ian Corbett, April 24, 1987, to the groups in Glasgow and in Paris.

Giazotto was not participating in these first meetings of the interferometric detectors community. However, about one year later…

May 1987: First French-Italian Proposal for a Interferometric Antenna

Proposta di

Antenna interferometrica a grande base per la ricerca di Onde Gravitazionali

INFN sezione di Pisa e Universita' di Pisa:
Raffaele Del Fabbro
Angela Di Virgilio
Adalberto Giazotto
Hans Kautsky (Fermilab, FNAL, Batavia USA)
Vinicio Montelatici (ENEA, Frascati Italia)
Diego Passuello
Arnaldo Stefanini

Universita' Di Napoli
Fabrizio Barone
Riccardo Bruzzese
Antonello Cutolo
Maurizio Longo
Leopoldo Milano
Salvatore Solimeno

CNR. Frascati
Franco Bordoni
Franco Fuligni
Valerio Iafolla

Universita' di Salerno
Innocenzo Pinto

CNRS-Univ. Pierre et Marie Curie
Gravitation et cosmologie Relativiste (Orsay-Paris)
Alain Brillet
C. Nary Man
David Shoemaker
Philippe Tourrenc
Jean-Yves Vinet

Pisa, 12 maggio 1987

- **An urgent proposal:** pressure from the Italian side to submit a proposal to INFN, in time to be included in the next five-year funding plan (*Piano quinquennale 1988-93*)
- Critical mass: 4 Italian groups joining the effort
- No optical group among the Italian teams: fundamental role of the Orsay group in the proposal

May 1987: First French-Italian Proposal for a Interferometric Antenna

4) Giustificazione di questo progetto nel piu' ampio contesto internazionale.

Se per un certo tempo questo progetto dovesse essere l'unico, e' chiaro che si dovrebbe mettere l'accento sulla "strategia delle basse frequenze": infatti oggetti periodici come binarie coalescenti sono le sole sorgenti che possono essere rivelate senza ambiguita' da una sola antenna. Inoltre, se si verificasse questa condizione, questa antenna sarebbe di enorme importanza per la comunita' scientifica internazionale, in quanto potrebbe anche servire come laboratorio di test per componenti e tecnologie.

In un contesto piu' ottimistico, cinque e' il numero ottimizzato di antenne che occorrono. Quattro antenne in coincidenza sullo stesso evento darebbero informazioni complete con lo schema della Relativita' Generale, mentre cinque ne permetterebbero la verifica. Questa condizione sarebbe soddisfatta se le antenne progettate fossero tutte realizzate (due americane, una britannica, una tedesca e una italo-francese).

In ogni caso, qualunque siano le decisioni degli altri Stati, il nostro progetto e' ben giustificato, sia come parte del primo "array" di antenne interferometriche nella regione del KHz, sia come antenna unica in quanto funzionante alle basse frequenze.

Main feature distinguishing the antenna from the German, British and American projects:

We will attempt to be the first in exploring the low frequencies […]. The Italian group achieved an expertise in the low frequency strategy, which is the not comparable to any other in the world.

The low frequency strategy would thus justify the building of the French-Italian antenna, even in the pessimistic hypothesis that no other interferometric detector was to be approved in the near future.

A strong peculiarity: being independent from the destiny of the other interferometric projects and from the collaboration with other comparable experiments

The difficult position of the Orsay group

- No laboratory of **IN2P3** (Institut national de physique nucléaire et de physique des particules, part of CNRS) was committed in the research activity of Brillet's group. **Pierre Lehman**, director of IN2P3 (1983-1992), was very interested, but could not commit IN2P3.

- A part from the brief experimental work of the group of Bonazzola in Meudon, in the early 70s, reproducing a Weber-type experiment in coincidence with the ones in Munich and in Frascati, in France there had been no other experimental activity in the field of GW detection.

- Instead, many theoretical studies had been carried out on the sources of GWs by Thibault D'Amour, Nathalie Deruelle, Silvano Bonazzola , and on the performances achievable by different types of resonant, electromagnetic or elasto-optical detectors by Philippe Tourrenc, Christian Bordé and Jean Yves Vinet.

- Differently from what happened in Italy, the research activity on GW detection was strongly supported by the French theoretical physicists and astrophysicists.

- When the first French-Italian proposal was submitted in May 1987 to INFN, no big project for GW detection had been ever financed by CNRS.

The difficult position of the Orsay group

Philippe Tourrenc, 80s

The Orsay group ran the risk of having a vassal position in the tripartite collaboration with Glasgow and Garching: all the 3 had expertise in optics and interferometry, but British and Germans had started several years before the activity in the GW detectors, had their own 10 m and 30 m prototypes, they had been collaborating more closely.

Alain Brillet, 90s

Instead, the scientific complementarity of Pisa and Orsay group, was a trigger to collaboration rather than to competition.

The position of the Pisa group

- Pisa group was as small as Brillet's. Giazotto did not have at the time any particular influential position in Italian physics, he became director of research inside INFN section of Pisa in 1989.

- No expertise in laser physics and optics: Pisa group lacked what was felt as the chore expertise for the new generation of GW detectors

- From the 1987 proposal: a long based interferometric antenna "would allow France and **our Country, already excelling in the technology of cryogenic resonant bar detectors**, to keep a high technological level also in this very complex research field."

- In the 80s the team of **Edoardo Amaldi and Guido Pizzella in Rome had an International leading role in the field of cryogenic resonators** for GW detection. The 2300 kg, 3 m long cryogenic bar Explorer, built by the Roman group at CERN, was the first antenna reaching the nominal sensitivity and stability over long periods (1990) and for several years the most sensitive GW detector in the world.

INFN had already a strong background in GW research.

First meeting of the European GW detectors working group

1987, June 17: Rutherford-Appleton Lab - Chilton (Oxford)

NOT FOR GENERAL CIRCULATION

Notes on first meeting of European Gravitational Wave Detector Working Group

17 June 1987 at RAL

Present:-

A Brillet (Orsay, Paris)
I F Corbett (RAL)
J Hough (Glasgow)
G Leuchs (MPI, Garching)
B F Schutz (Cardiff)
Ph. Tourrenc (Paris)
W Winkler (MPI, Garching)

Giazotto was not yet part of the Working group

1. OBJECTIVES OF WORKING GROUP

1.1 To prepare and present the scientific case for constructing and exploiting an array of collaboratively funded and constructed Gravitational Wave Detectors, taking some account of financial constraints.

1.2 To discuss and formulate an agreed collaborative policy covering the design, construction, commissioning, operation and development of detectors.

1.3 To propose possible management structures for the project.

1.4 To summarise conclusions and recommendations in a report to be presented to BMFT, CNRS, INFN and SERC.

Rutherford-Appleton Lab - Chilton (Oxford), June 17, 1987

2.2 Orsay, Paris - A Brillet and Ph. Tourrenc

The joint Pisa-Paris proposal has been presented to INFN and a first decision is expected by 19th June. A final INFN decision is not expected before the end of 1988. There are three non-nuclear projects currently before INFN - the interferometer, 6 bars and the gyroscope.

A joint Pisa-Paris proposal for an antenna at Nancay will be made to CNRS some time in 1988.

Tourrenc is opening discussions with some Spanish astrophysicists (Grenada) with a view to interesting them in joining the project.

2.3 Glasgow/Cardiff - J Hough

The financial situation is essentially unchanged but the University of Glasgow now has Outline Planning permission for one of its sites (Buchlyvie) and expects to obtain permission for the Tentsmuir site soon. There have been vigorous environmental objections to this site.

3. OPTIMAL EUROPEAN ARRAY

Bernard Schutz opened the discussion by outlining the case for the minimum European array of 2 detectors of comparable sensitivity, sited about 1000 km apart, which gives reasonable time difference resolution and sensitivity to stochastic radiation.

It was agreed that neither existing or projected bar projects could be regarded as of comparable sensitivity.

In the discussion which followed it was agreed that the case that the Working Group should concentrate on presenting to the funding bodies would be based on 3 detectors spaced roughly 1000 km apart, to be built simultaneously. The arm length would ultimately be dictated by the funds available but should be as long as possible: 3 km was felt reasonable.

The case for three detectors would be argued for both possible outcomes of the US project, viz no US detectors or two US detectors.

First meeting of the European GW detectors working group

First decision expected by INFN on 19 June. Final decision at the end of the year.

Rutherford-Appleton Lab - Chilton (Oxford), June 17, 1987

First meeting of the European GW detectors working group

4. COOPERATION AND COLLABORATION

It was unanimously agreed that all antenna should be built as collaborative ventures, with common design features, data acquisition systems and protocols.

In this context there was some criticism of the way the proposal to the INFN had been prepared without informing or consulting the other groups in the EC collaboration. This action was defended on the grounds of necessity and urgency. NO

5. ORGANISATION OF COLLABORATION

There was some discussion of how a multilateral collaboration could be organised. Given the wide agreement, there would appear to be no insoluble problems.

It was unanimously agreed that no new organisation, with its own bureaucracy, would be created as a result of this initiative.

6 WORKING PARTY REPORT

ISTITUTO NAZIONALE DI FISICA NUCLEARE

Doc. Gen. n. 905/87
16 Dicembre 1987

Esteso

PIANO QUINQUENNALE DELL'ISTITUTO NAZIONALE DI FISICA NUCLEARE PER GLI ANNI 1989-1993

(Documento approvato dal Consiglio Direttivo dell'INFN il giorno 16 Dicembre 1987)

On the 19th of June INFN agreed to insert the proposal of a large based interferometric antenna for GWs in the 1989-1993 five-year planning of INFN, to submit to the Italian Ministry of Research in December for approval.

Nel campo dello studio delle onde gravitazionali l'I.N.F.N. sta seguendo tre metodiche sperimentali, delle quali solamente una riguarderá un esperimento che verrá installato sotto il Gran Sasso e che consiste nella realizzazione di un sistema di antenne gravitazionali raffreddate alla temperatura di 100 milli-Kelvin. Le altre due metodiche fanno uso: la prima, di interferometria laser a grandi distanze (circa 10 km) con la quale sará possibile esplorare, oltre alle sorgenti impulsive, anche quelle periodiche con lo studio della regione della bassa frequenza; la seconda, delle proprietá superconduttrici della materia mediante una apparecchiatura che dovrebbe permettere anche la misura di effetti di relativitá generale dovuti a correnti di massa.

Reactions to the 1987 French-Italian Proposal

July 16, 1987, Corbett to Tourrenc:

I would like to congratulate the Italian group and your group in France, on ***your success convincing INFN*** *of the value of building a long baseline interferometer. I am genuinely pleased at what I hope will turn out to be a break-through in European funding. Although the preparation and presentation of this proposal generated* ***some ill-feeling****, I hope we can put all this behind us.*

- Coordination between the different projects was a fundamental feature to convince the funding agencies

- Coordination justified from a scientific point of view by the need to make coincidence detection and by the complexity of the experiment and the apparatus to be built, for which a large-scale cooperation was necessary from a technical-scientific and financial point of view

- The projects were to be presented as independent but coordinated parts of a scientific cooperative endeavour on a European scale: the fundamental constituents of a large European gravitational observatory.

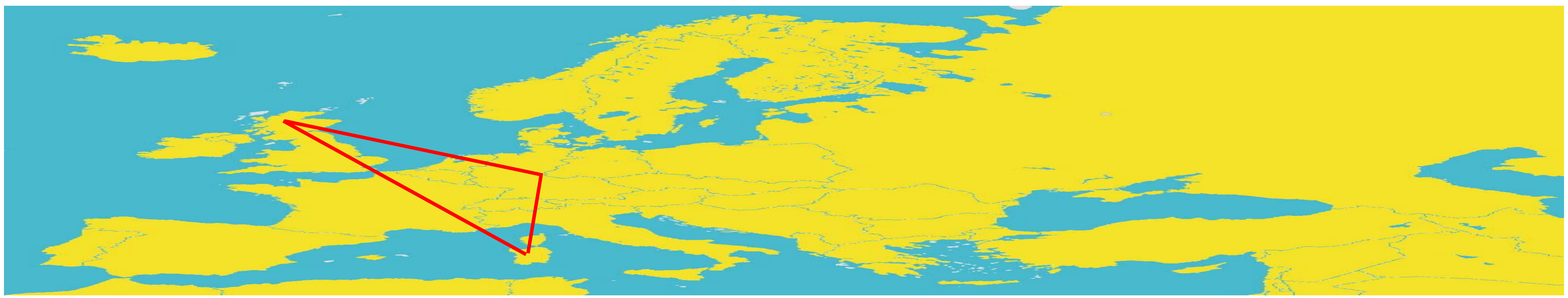
- The French-Italian 'surprise' project violated the common strategy and put the other groups in an embarrassing position towards their funding agencies [Interview made by the author to Schutz and Hough, August 2018].

A change in the strategy: 3 European antennas instead of 2

With the perspective of the Italian-French antenna, the scenario was widening:

the possibility of having a real European observatory - able to make gravitational astronomy autonomously in the future, independently from USA - is certainly a strong scientific motivation in support of individual national projects.

It is therefore essential for European groups to justify with solid scientific motivations the need for an array of at least three antennas, in order to support all three projects proposed before their respective funding agencies.



Calculations by Schutz and Tourrenc, to justify a European 3-interferometer network

B.F. Schutz September 1987

Outline case for building 3 laser interferometric detectors in Europe

There are two main considerations that show the benefit of constructing as many detectors as one can afford:

(i) More detectors mean capturing more gravitational wave events. This is partly because of greater sky coverage, but mainly because the decreasing risk of 'random' coincidences caused by noise allows one to operate with lower thresholds and therefore to see a greater volume of space.

(ii) More detectors mean a better reconstruction of the gravitational wave, therefore more physics and astrophysics.

I will address both of these in the context of two possible configurations, with or without any detectors in the USA.

(i) Increase of sensitivity with increasing number of detectors

Given Gaussian noise, it is not hard to calculate the probability that two identical independent detectors will both be above a pre-set threshold at the same time. It is only slightly more difficult to include complications that a realistic network would have to deal with: detectors of different sensitivities, allowing for time-delay 'windows' within which noise-generated events ('false alarms') would simulate gravitational waves propagating at the speed of light, and the effect of filtering the data through a large number of statistically independent filters. For a network of up to three identical detectors (Europe going it alone), the following ratios of threshold X to noise σ will give only one expected false alarm per year under reasonable observing conditions:

number of detectors n	1	2	3
threshold X/σ	7.4	5.4	4.6

The observable volume V_n increases as the inverse cube of the threshold:

number of detectors n	1	2	3
V_n / V_1	1.	2.5	4.1

Next consider networks involving US detectors as well: let us consider two 4-km US detectors observing with either two or three 3-km European detectors:

number of detectors n	4	5
European threshold X/σ	3.6	3.2

The observable volume V_n increases by 42% from one configuration to the

CONDITIONS FOR A LARGE SCALE GRAVITATIONAL ASTRONOMY

PH. TOURRENC

I - Birth of large scale gravitational astronomy.

We studied large scale astronomy which means that h has to be weak ($h \leq 3.10^{-21}$ see Blair "Les Houches 1982").

We assumed homogeneity, isotropy,..etc... for space, and random polarizations for G-waves.

We defined σ = r.m.s. fluctuation in the measurement of $\delta L/L$ and we assumed a Gaussian noise.

We used a factorial analysis method.

Then we proved

1) $$N_J = \frac{K}{h_0^3 \sigma^3} \cdot 0{,}3\, I$$

K depends only on astrophysics data.

I depends only on the array choosen

σ depends only on the experimental performances.

N_J is the number of signal detected per day (with a likely low noise)

1) We demanded that $N_J > N_0 \sim$ (11/year)

2) we demanded that $(N_J)_\Delta / N_S > u_0 \sim 4\text{-}8$ where N_S is the number of spurious signal (noise or low precision) and $(N_J)_\Delta$ is the number of detected signal coming from a direction Δ within its error box, $(\Delta\Omega)_\Delta$

Second meeting of the European GW detectors working group

EUROPEAN GRAVITATIONAL WAVE WORKING GROUP

Second Meeting: Paris 30 September 1987

Corbett, preparing the meeting

1. I have invited Adalberto Giazotto from INFN, Pisa to attend.

2. We have three principal tasks at this meeting:

   2.1 Agree on the preparation and presentation of the scientific case for the simultaneous construction of three antenna in Europe.

   2.2 Agree on how we organise the collaboration.

   2.3 Agree on the collaboration strategy in dealing with the funding bodies.

Paris, September 30, **1987**

This time Giazotto is invited, too. He participates for the first time to the negotiations among the European groups.

11. Within the collaboration, groups would continue to be free to work in their own way, and in particular would continue to seek support for their own project.

12. However, they should also make it clear to their funding bodies that their project has to be seen as part of a collaborative European effort with the full backing of the other groups, and that it is not in competition with the other proposals.

13. Every group undertakes not to do anything that would damage the approval prospects of another project.

Next step: Produce a a report about the European collaboration to present to funding agencies!

A draft was prepared by Ian Corbett, but caused some indignation and was vividely criticized by the German and French groups

Gerd Leuchs, about the first draft written by Corbett (December 1987)

C o m m e n t s by the G a r c h i n g G r o u p :

We think it serves our common goal best if the various achievements from all groups are stressed on an equal basis, also with respect to priorities of chronology.

In comparisons with the bar detectors, the sensitivity in strain h is the more relevant one, and here the two groups at Garching and Glasgow are exactly abreast, which makes a much better political case.

In general, we consider it preferable not to start on a petty competition as to which group has contributed or first discovered or solved this or that particular part.
If we tried that, it might take ages until we can agree on a draft.

Finally...

Report of an Ad-Hoc Working Group on the Future of Interferometric Gravitational Wave Antennas in Europe.

March 1988

Membership of Working Group:

A Brillet CNRS - Univ. Pierre et Marie Curie, Paris

I F Corbett Rutherford Appleton Laboratory

A Giazotto INFN sezione di Pisa e Univ. di Pisa

J Hough University of Glasgow

G Leuchs Max-Planck-Institut fur Quantenoptik, Garching

B F Schutz University College, Cardiff

Ph Tourrenc CNRS - Univ. Pierre et Marie Curie, Paris

W Winkler Max-Planck-Institut fur Quantenoptik, Garching

SUMMARY

This report examines the scientific case for constructing interferometric gravitational wave antennas, and argues that a network of detectors is required if complete astrophysical observations are to be possible. For Europe this need is best satisfied by the construction of three independent, but networked, interferometers. For each instrument, the limiting background signal spectral density should be significantly better than 3.10-23/Hz (corresponding to a strain sensitivity of better than 10-21 for a 1 kHz bandwidth), over a frequency range extending from a few kilohertz down to tens of hertz, if possible. Such a sensitivity over a wide bandwidth could result in the annual observation of several hundred events of various origins.

Although the detailed scientific priorities and strategies that have been selected are different, the proposals presented to their respective funding bodies by UK, German and Italian-French groups already incorporate these goals, and the working group has established a framework for active collaboration between these groups. This is now operational, and five specialist groups have been formed to work on different aspects of the design of long-baseline interferometers. The aim is to find cost-effective solutions to the many common design problems whilst retaining the independence and flexibility necessary to respond to different funding scenarios.

Collaboration in the construction of detectors would probably best be done through conventional bi-lateral agreements.

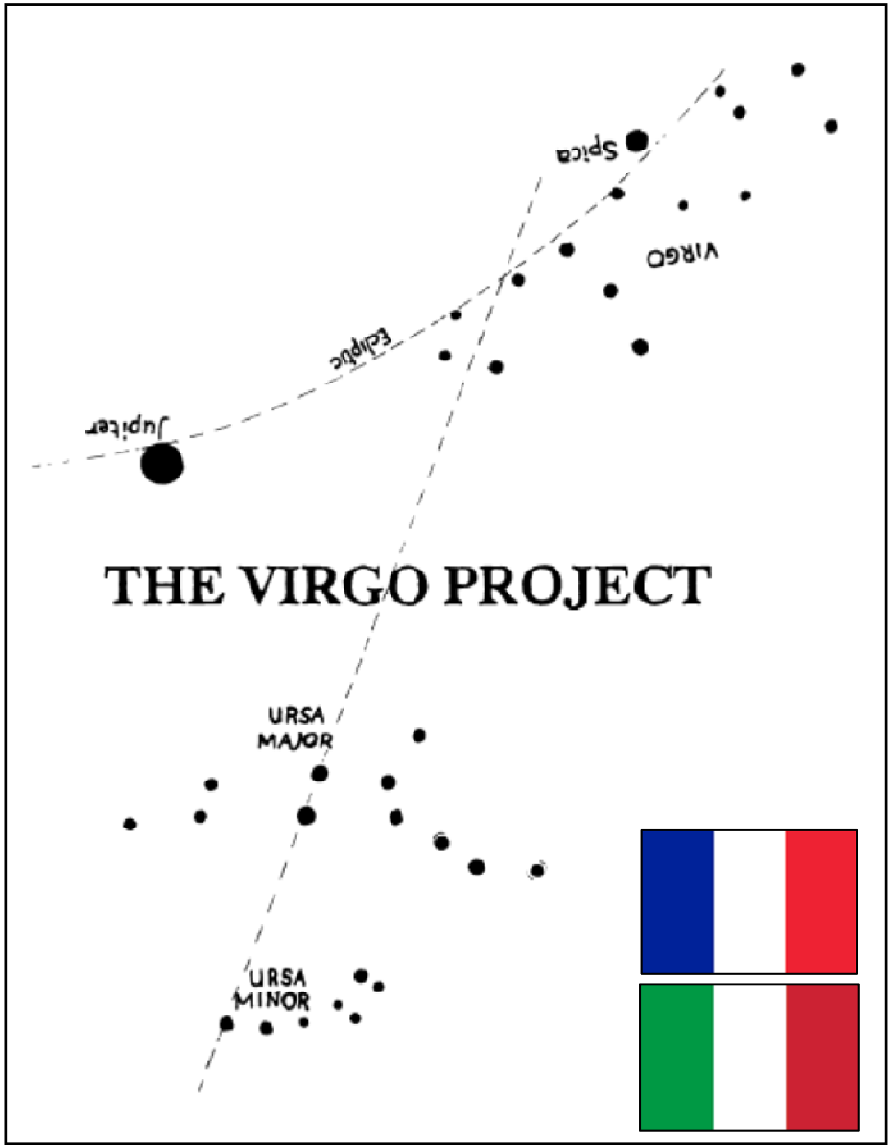
March 1988: the final EUROGRAV report

An array of three detectors in Europe would give the European groups the minimum independence necessary to enable Europe to maintain its leading position in the field.

Technically and scientifically the European groups have the capability to construct and operate a network that could make the first detection of gravitational waves and that could reach the critical number of three antennas that would see the birth of gravitational wave astronomy.

Three European detectors operating with an American array, built either simultaneously or subsequently, would become one of the most important astronomical instruments of the modern age.

1989 Proposals: from 3 to 2 European long based interferometers



London, November 1990

Big history intercepts the small community of gravitational waves

SERC

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Sir Mark Richmond ScD FRS
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Dr A Brillet
Laboratoire de Gravitation
et Cosmologie Relativistes
Battiment 104
Faculté des Sciences
91405 Orsay
France

Our Ref: P/SG/603

1 February 1991

Dear Dr Brillet

BRITISH-GERMAN GRAVITATIONAL WAVE PROJECT - GEO

Thank you for the letter of 17 January 1991 signed by yourself, Professor Giazotto and Dr Tourrenc.

The SERC and I fully recognise the importance of the GEO project in the international context of gravitational wave research and the fact that all the proposed projects are to some degree interdependent. I am also aware of the high regard internationally for the UK groups at Glasgow, Cardiff and Rutherford Appleton Laboratory and the scientific significance of this field of research. However, the overall SERC funding position for 1991/92 and subsequent years has been seriously undermined by the very poor Public Expenditure Survey outcome for science announced in November 1990. As a result SERC is having to examine the whole of its programme to assess its future direction and balance, and to determine where economies can be made with minimum scientific damage.

In the short term SERC is having to consider delaying participation in several projects by up to 5 years; GEO may well be one of these projects. This would be an enforced delay and does not signal decision or wish to withdraw from the project.

Sir Mark Richmond, Chairman of SERC, to Brillet – February 1, 1991

[…] the overall SERC funding position for 1991-92 and subsequent years has been seriously undermined by the very poor Public Expenditure Survey outcome for science announced in November 1990. […]
In the short term SERC is having to consider delaying participation in several projects by up to 5 years; GEO may well be one of these projects.

Berlin, November 1989

Big history intercepts the small community of gravitational waves

===

Resent-To: ALAIN BRILLET <BRILLET@FRCPN11>
Date: Fri, 05 Jul 91 13:43:52 EST
From: KARSTEN DANZMANN <KVD@DGAIPP1S>
To: ROBBIE VOGT <VOGT@CALTECH>

----------------------------Original message----------------------------

Dear Robbie:

Sorry I was not in Japan to meet you. But it was a good time for me to take a short vacation and I thought I did not have anything new to report. But maybe I should have gone. So here are some of my thoughts

The whole approval situation in Europe is very diffuse and confusing. Scientifically everything is in order. All review commissions in all 4 countries have approved the projects. And the german BMFT commission on large projects in basic research has just given the gravity wave detector the second highest priority of All BMFT-funded projects. But politically the situation is unsatisfactory. The reasons are partly financial. German unification is taking a huge toll on the BMFT budget. Thousands of scientists from the east have to be laid off or taken over. But both options are expensive. The research institutes of the old eastern academy of sciences have to be dissolved and new structures have to be built up, and so on....It is not only money, but also manpower. Everybody at BMFT is so busy restructuring the East that nobody has time to even think about Gravity waves. And if they do, the results are confusing. After the British have partly withdrawn financial support, Minister Riesenhuber is not willing to take over all of the reponsibility for GEO. And in general he has a faible for European Integration. So other european partners are being approached by BMFT. But these contacts are on a very political level and we are glad if we hear of the results. And so far there are not many.

Danzmann, leader of Garching group after Leuchs (since 1989), to Vogt, director of LIGO - July 5, 1991

German unification is taking a huge toll on the BMFT budget. Thousands of scientists from the east have to be laid off or taken over. But both options are expensive. The research insitutes of the old eastern academy of sciences have to be dissolved and new structures have to be built up, and so on… It is not only money, but also manpower. Everybody at BMFT is so busy restructuring the East that nobody has time to even think about Gravity waves. […] Minister Riesenhuber is not willing to take over all the responsability for GEO. And in general he has a faible for European Integration.

BMFT: German Federal Ministry of Education and Resaerch

Accelerating science to 3G…

1^{st} Generation: Room-temperature resonant bars

2^{nd} Generation: Cryogenic resonant bars (& ultra-cryo)

3^{rd} Generation: Interferometric detectors

1^{st} Generation: Interferometric detectors

2^{nd} Generation: Advanced interferometric detectors

3^{rd} Generation: Future ground-based interferometric detectors

A change of scale in GW research

A change of scale in GW research

Amaldi's and Pizzella's group, building Explorer cryogenic bar, Frascati 1973

Big change of scale in funding, manpower and scientific skills needed to build a long based interferometric detector

Virgo people - Cascina, 2003

Some problems faced by the European groups in their attempts for establishing a European collaboration

- Very small groups, used to small bench-top experiments.
- Lack of a strong GW community: no coordinating committee (GWIC was born in 1997), no dedicated periodic conferences (Edoardo Amaldi conference was born in 1994)
- Will the experiments be successfull?
- Scientific disagreements:

French-Italian: no prototypes (different timings in the start of research activity)
Fabry-Perot cavities-Delay lines
Low frequency strategy

- Competition/Collaboration. Coincident esperiments are needed to detect bursts of GWs and make GW astronomy: a chance for common strategy, but also a burden to individual ambitions.
- National interests. Hot issue: the choice of the site!
- What kind of agreement/collaborative framework should be made?

= What's better today, looking forward to 3G interferometers!

…to be continued in the next episode…

Stay tuned:
A. La Rana, *Virgo and the emergence of the international gravitational wave community*, in *The Renaissance of General Relativity,* eds A. Blum, R. Lalli and J. Renn (Max Planck Institute for the History of Science), Einstein series, Birkhausen, 2019

Thank you for your attention!

BACK UP SLIDES

1987, April 16: Giazotto to Brillet (1 month before presenting the first Virgo proposal to Infn)

1) WE APPRECIATE A LOT YOUR INTENTION OF COLLABORATION AND WE BELIE-
VE THAT IT SHOULD BE ADOPTED THE SECOND HYPOTHESIL YOU SUGGEST:
A COMMON GOAL FOR THE TWO GROUPS. THIS GOAL COULD BE AT PRESENT
THE COSTRUCTION OF A LARGE ANTENNA IN ITALY, MAINLY SUPPORTED BY
INFN BUT WITH YOUR TECHNICAL AND FINANCIAL CONTRIBUTION TOO. IN
THE FUTURE, WHEN A PROPOSAL WILL BE PRESENTED TO THE CNRS, WE ARE
READY TO CONTRIBUTE IN AN EQUIIVALENT WAY. THE NECESSITY OF TWO
OR MORE OF SUCH ANTENNAS I BELIEVE IS VITAL BECAUSE COINCINDENCES
ARE NEEDED, AS BAR ANTENNAS DO, AND THIS SHOULD BE STRESSED IN THE
PROPOSAL.

2) OUR SCIENTIFIC GOAL IS TO BUILD A LARGE BASE ANTENNA (3KM)
WORKING AT HIGH FREQUENCY (1000HZ) BUT HAVING SEISMIC NOISE AND
LASER NOISE REDUCTION FOR TRIYNG TO GO AT MUCH LOWER FREQUENCY
AS WELL, AS YOU WELL KNOW. AT THE PRESENT STATUS OF THE ART WE
THIN K THAT DEFORMABLE DELAY LINES WITH PERHAPS 20 BEAMS
PROBABILITY OF SUCCES BUT WE DO NOT EXCLUDE THAT FABRY PEROT
COULD BE ADOPTED IF THIS IS THE CASE. WITH THE SAME PHYLOSOPHY
WE THINK OF USING FEW AR LASER IN PARALLEL BUT WE DO NOT EXCLUDE
YAG (I HAVE JUST RECEIVED AN OFFER OF 300.000 US DOLLARS FOR N.5
LASER INNOVA 20 20W). OBRIOUSLY IT WILL BE, VERY RELEVANT YOUR
EXPERIENCE IN THIS MATTER.

The long road to lay the foundation stone

1992, June: Approval of the Virgo Project by the French Minister Hubert Curien.

1993: Provisional Virgo Council formed in April and final approvement by INFN in September.

1994, **June 27**: President of INFN Luciano Maiani and President of CNRS Francois Kourilsky sign the agreement to build Virgo in Cascina. Funding: 76 MegaEcu (European Currency Unit), about 50 million euros.

1995, September 25: Publication on Gazzetta Ufficiale of the expropriation resolution of the Italian Minister of Public works, for the fields in Cascina.

1997: **Construction begins!**

1994: the final CNRS-INFN Agreement

ACCORD
concernant la Réalisation de
l'Antenne de Détection
des Ondes Gravitationnelles
VIRGO

Le Centre national de la Recherche scientifique, Etablissement Public à caractère Scientifique et Technologique - ci-après désigné par les initiales CNRS et dont le siège social est sis 3, rue Michel-Ange, F75794 Paris Cedex 16, représenté par son Directeur Général, M. François Kourilsky,

et

l'Istituto Nazionale di Fisica Nucleare, institut publique pour la recherche scientifique - ci-après désigné par les initiales INFN et dont le siège social est sis via Enrico Fermi 40, I 00044 Frascati, représenté par son Président, M. Luciano Maiani,

ci-après désignés les Parties ;

CONSIDÉRANT que la détection des ondes gravitationnelles offrira

dans le domaine de la physique fondamentale

- une preuve directe de l'existence des ondes gravitationnelles ;

- un mode d'investigation des caractéristiques tensorielles du champ gravitationnel ;

dans le domaine de l'astronomie et de l'astrophysique

- un nouveau moyen d'observation des objets lointains, en sus des ondes électromagnétiques et des neutrinos ; il s'agira d'un instrument unique pour la détection des phénomènes très énergétiques tels que l'effondrement des supernovae et des binaires serrées ;

CONSIDÉRANT qu'une collaboration dans ce domaine existe déjà depuis de nombreuses années entre scientifiques français et italiens ;

conseguenza il presente Accordo sarà modificato tramite una clausola aggiuntiva.

ARTICOLO 14 - CONTROVERSIE

Le Parti risolveranno amichevolmente ogni controversia che potrebbe risultare dalla interpretazione o dalla applicazione del presente Accordo.

ARTICOLO 15 - SCALA DEI TEMPI

La data di acquisizione del sito costituisce il tempo zero della scala dei tempi previsti per la realizzazione del progetto (Allegato B). Nel frattempo la progettazione e la realizzazione di prototipi di sottosistemi nonché altre attività definite dal Consiglio VIRGO, sono o potranno essere condotte senza relazione temporale con l'acquisizione del sito.

ARTICOLO 16 - ENTRATA IN VIGORE

Il presente Accordo entrerà in vigore dopo essere stato approvato dalle Autorità competenti delle Parti.

ARTICOLO 17 - DURATA

A meno che decidano di comune accordo di mettere fine alla loro collaborazione, le Parti si impegnano a partarla avanti, oltre alla fase di costruzione, per una durata minima di gestione di cinque anni, conformemente a quanto previsto dall'articolo 1. del presente Accordo.

ARTICOLO 18 - DISPOSIZIONI FINALI

Il presente Accordo é redatto in quattro esemplari originali, due in versione francese e due in versione italiana, entrambe facenti ugualmente fede.

Pisa li, 27 Juin 1994

Per il CNRS	Per l'INFN
François KOURILSKY Direttore Generale	Prof. Luciano MAIANI Presidente

Caltech and MIT join efforts for a GW interferometric project

- Late 70s: Thorne triggers the creation of an experimental gw group at Caltech
- 1979: Drever moves from Glasgow to Caltech to lead the experimental activity, joined in 1980 by Stan Whitcomb
- 1980: NSF approves funding for: 1) 40 m prototype interferometer in Caltech; 2) 1.5 m prototype at MIT (Weiss); 3) preparation of technical and cost study for long-baseline interferometer.
- 1984: Caltech and MIT sign an agreement for the joint design and construction of LIGO, under the leadership of Drever, Thorne and Weiss. Rochus Vogt appointed director of LIGO in 1987.
- 1989: joint Caltech-MIT proposal for LIGO construction, submitted to NSF

Massachusetts
Institute of
Technology

Leuchs, about the first draft written by Corbett (December 1987)

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C o m m e n t s   by the   G a r c h i n g   G r o u p :

We think it serves our common goal best if the various achievements
from all groups are stressed on an equal basis,
also with respect to priorities of chronology.

In comparisons with the bar detectors, the sensitivity in strain h
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Glasgow are exactly abreast,
which makes a much better political case.

In general, we consider it preferable not to start on a petty
competition as to which group has contributed or first discovered
or solved this or that particular part.
If we tried that, it might take ages until we can agree on a draft.
```

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* The Garching group has developed a 30m delay line interferometer,
* with which they achieved a strain sensitivity of the order of
* 10-19/ /Hz in 1986.
 % we prefer strain h, that's what counts,
PF1=Help     PF2=Next        PF3=Quit    PF4 =Print  PF5 =Reply     PF6 =F
PF7=ScrollUp PF8=ScrollDown PF9=Discard PF10=Switch PF11=Log       PF12=C
 >>> MAIL 86.359 <<< From: GDL at DGAIPP1S                        Line 115
====>
 % we prefer strain h, that's what counts,
 % and what allows a comparison with bars.
 % let's gracefully forget that a sentence like the following
 % ever found its way into the original :
%- Since that time various modifications have been
%- incorporated which should lead to a displacement sensitivity
%- comparable to that of the Glasgow prototype.

The Glasgow group has continued to develop their 10m prototype
* and has recently achieved a record in their displacement
* sensitivity of 1.2 10-18m/ /Hz at about 1 kHz,
* also corresponding to a strain in the order of 10-19/ /Hz.
 %- Further improvements currently being implemented should result
 %- in this being reduced to below 10-18m/ /Hz.

*
```

An excerpt from Corbett's criticised draft

ISTITUTO NAZIONALE DI FISICA NUCLEARE

ROMA (Italy) ...21...Settembre 1989
Piazzo dei Caprettari, 70 (00186)
Tel. 65 61 362 - 65 48 081 - 65 47 924
telex 614125

Al ch.mo Prof. Nicola Cabibbo
Presidente dell'I.N.F.N.
Piazza dei Caprettari, 70
R o m a

e p.c. ai Membri della Giunta
Esecutiva dell'I.N.F.N.
Piazza dei Caprettari, 70
R o m a

Al Ch.mo Prof. A. Giazotto
P i s a

Caro Presidente,

nella riunione del 19 Settembre la Commissione Scientifica Nazionale II ha discusso la proposta VIRGO.

L'esperimento proposto e' di grande interesse scientifico. Si propone di portare la ricerca sulle onde gravitazionali ad una sensibilita' di almeno due ordini di grandezza superiore a quello raggiungibile con le antenne risonati. Questa sensibilita' e' sopratutto interessante in quanto e' estesa ad una larga banda di frequenze ed, in particolare, alle basse frequenze dove l'esperimento e' unico e l'interesse scientifico grande.

La Commissione valuta molto positivamente la collaborazione che si e' stabilita con i gruppi francesi e ritiene indispensabile la loro partecipazione.

In base a quanto a tutt'oggi realizzato dai proponenti, appare raggiungibile una sensibilita' almeno pari a quella prevista con gli sviluppi attesi dalle antenne risonanti nei tempi proposti nel progetto. Quando queste prestazioni saranno raggiunte, e' auspicabile che una frazione significativa del tempo sia dedicato alla presa dati. Tra non molti anni, con la contemporanea presenza delle due antenne criogeniche sul nostro territorio, si verrebbe cosi' a costituire un osservatorio di onde gravitazionali, basato su tre stazioni

1988: Del Fabbro, Di Virgilio, Giazotto, Kautzky, Montelatici, Passuello, *First results from the Pisa seismic noise super-attenuator for low frequency gravitational wave detection*, Phys. Lett. A 132, 237 (1988).

The group of Pisa had succeeded in demonstrating to be able to obtain attenuations of 10^{10} to around 10 Hz.

Giazotto: *It was the key result; on its base, Italy has approved Virgo.*

Paolo Strolin, President of INFN Commission II, to Nicola Cabibbo, President of INFN, September 21, 1989

Una piccola antenna sotto i riflettori…

Edificio Enrico Fermi, Sapienza. «Antenna gravitazionale criogenica con la quale il gruppo di Roma ha effettuato tra il 1975 e il 1979 le prime misure di rumore browniano

Roma, 1970: nasce il gruppo di ricerca sperimentale sulle OG

Guido Pizzella e Edoardo Amaldi, Conferenza di Relatività Generale a Padova,1983. Foto scattata da Emilio Segrè.

Obiettivo: seconda generazione di rivelatori, le barre criogeniche

The Munich-Frascati Experiment

Main Papers:

- **1972**: Bramanti D., Maischberger K., *Construction and Operation of a Weber-Type Gravitational-wave Detector and of a Divided-Bar Prototype*, Lettere al Nuovo Cimento, Vol. 4, n°17, Agost 1972, 1007
- **1973**: Bramanti D., Maischberger K., Parkinson D., *Optimization and data analysis of the Frascati Gravitational-Wave detector*, Lettere al nuovo cimento 7, 14 4. Agosto 1973, 665.
- **1975:** *Results of the Munich-Frascati Gravitational Wave experiment*, Lettere al nuovo cimento, 12, 4, 25. gennaio 1975, 111
- **1978:** Kafka P., Schnupp L. (1978), Final Result of the Munich-Frascati Gravitational radiation Experiment, Astron. Astrophys., 70, 97-103

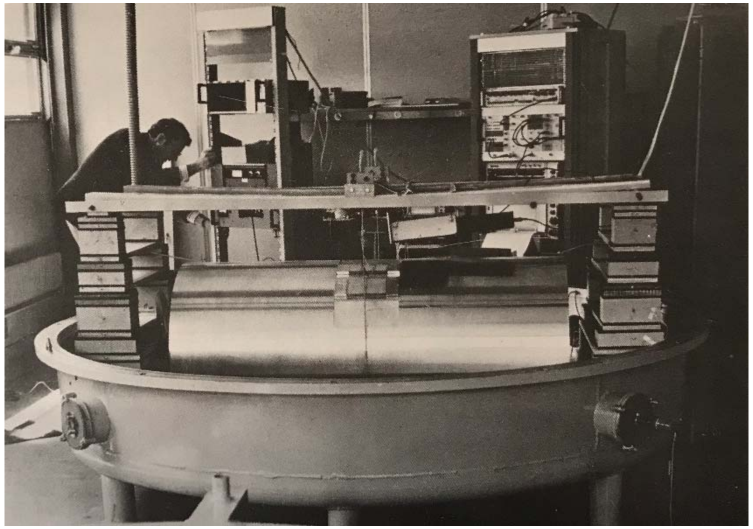
At the time of room temperature bars:

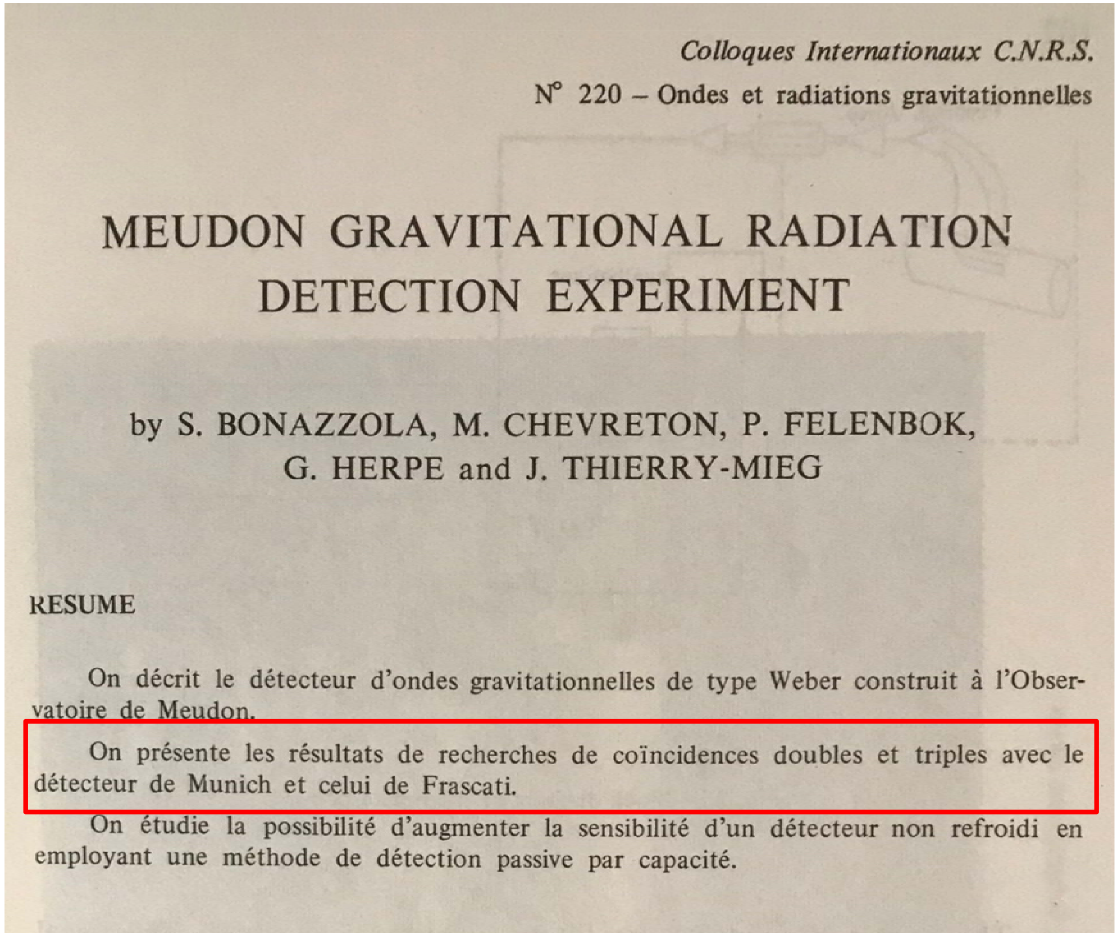
Their experiment unquestionably provided the most stringent test of all for the detection of gravity waves.

Levine J.L., *Early Gravity-Wave Detection Experiments*, 1960-1975, Phys. perspect. 6 (2004) 42-75

The Munich-Frascati-Meudon Experiment

Silvano **Bonazzola**, Observatoire de Paris-Meudon





Colloques Internationaux C.N.R.S.
N° 220 – Ondes et radiations gravitationnelles

MEUDON GRAVITATIONAL RADIATION DETECTION EXPERIMENT

by S. BONAZZOLA, M. CHEVRETON, P. FELENBOK, G. HERPE and J. THIERRY-MIEG

RESUME

On décrit le détecteur d'ondes gravitationnelles de type Weber construit à l'Observatoire de Meudon.

On présente les résultats de recherches de coïncidences doubles et triples avec le détecteur de Munich et celui de Frascati.

On étudie la possibilité d'augmenter la sensibilité d'un détecteur non refroidi en employant une méthode de détection passive par capacité.

- **Bonazzola**, **Chevreton**, **Felenbok**, **Herpe**, **Thierry-Mieg** (**1973**), *Meudon gravitational radiation detection experiment,* Colloques internationaux du Centre National de la Recherche Scientifique, 18-22 Jun 1973

The start of GW interferometric detectors in Garching

GW Interferometry:
1962: M. E. Gertsenshtein and V. I. Pustovoit, Sov. Phys. JETP 16, 433 (1962)
1971: G. E. Moss, L. R. Miller, and R. L. **Forward**, Photon-Noise-Limited Laser Transducer for Gravitational Antenna, Appl. Opt. 10, 2495 (1971)
1972: R. **Weiss**, Electromagnetically Coupled Broadband Gravitational Antenna, Quarterly Progress Report, MIT Research Lab of Electronics 105, 54 (1972).

Walter Winkler (left, background) and Karl Maischberger, 1977

1974: in Garching (near Munich, were Billing's group had moved) started the activity for building an interferometric GW detector. Poineering work: The **30 m prototype** was the first to reach the shot noise limit in the '80s. Results which were essential for the future funding of LIGO.

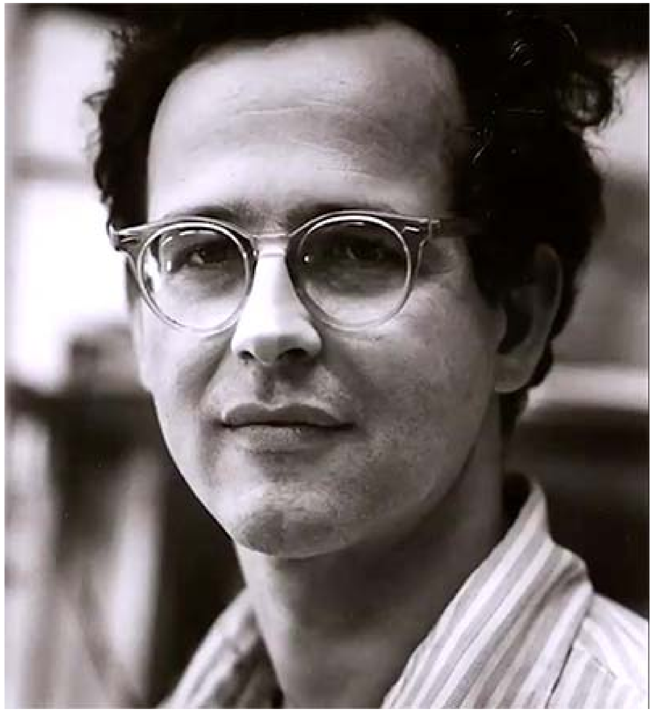
QUARTERLY PROGRESS REPORT

No. 105

APRIL 15, 1972

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
RESEARCH LABORATORY OF ELECTRONICS
CAMBRIDGE, MASSACHUSETTS 02139

LIGO-P720002-00-R



Rainer Weiss

Electromagnetically Coupled Broadband Gravitational Antenna

Quarterly Progress Report, MIT Research Lab of Electronics 105, 54 (1972)

The start of Rome-Louisiana-Stanford collaboration

William Hamilton (Louisiana State University)

William Fairbank (Stanford University)

Guido Pizzella (Sapienza University)

- **January 1971**: **Amaldi** receives confidentially from Remo **Ruffini** the Stanford and Louisiana proposal for a detector consisting in a 5 ton aluminum bar cooled to very low temperature (0.003 K) employing a SQUID amplifier coupled to a resonant transducer.

- **April 1971**: **Pizzella**, **Cerdonio**, **Marconero** and **Modena** go to USA and visit Stanford (Fairbank), Louisiana (Hamilton) and the Bell Telephone Laboratory (Tyson) had constructed a GW Weber type detector.

Still few years later…

1960-1975: GW detectors in a glimpse

- **1960**: J. **Weber**, *Detection and generation of gravitational waves*, Phys. Rev.
- **1969**: J. **Weber**, *Evidence for Discovery of Gravitational Waves*, Phys. Rev. Lett.

- **Room-temperature bar detectors**

Research Groups: Maryland-Argonne (**Weber**), Frascati (**Maischberger**), Munich (**Billing**), Meudon (**Bonazzola**), Bell Labs (**Tyson**), IBM-NY (Garwin), Rochester (**Douglass)**, Glasgow (**Drever**), Reading (**Allen**), Bristol (**Aplin**), Moscow (**Braginski**), Tokyo (**Hirakawa**)

- **Cryogenic bar detectors**

Research Groups: Stanford (**Fairbank**), Baton Rouge (**Hamilton**), Rome (**Amaldi**)

- **Interferometric detectors**

Papers

1962: M. E. **Gertsenshtein** and V. I. **Pustovoit**, *On the detection of low frequency gravitational waves*, Sov. Phys. JETP 16, 433

1971: G. E. **Moss**, L. R. **Miller**, and R. L. **Forward**, *Photon-Noise-Limited Laser Transducer for Gravitational Antenna*, Appl. Opt. 10, 2495

1972: R. **Weiss**, *Electromagnetically Coupled Broadband Gravitational Antenna*, Quarterly Progress Report, MIT Research Lab of Electronics 105, 54

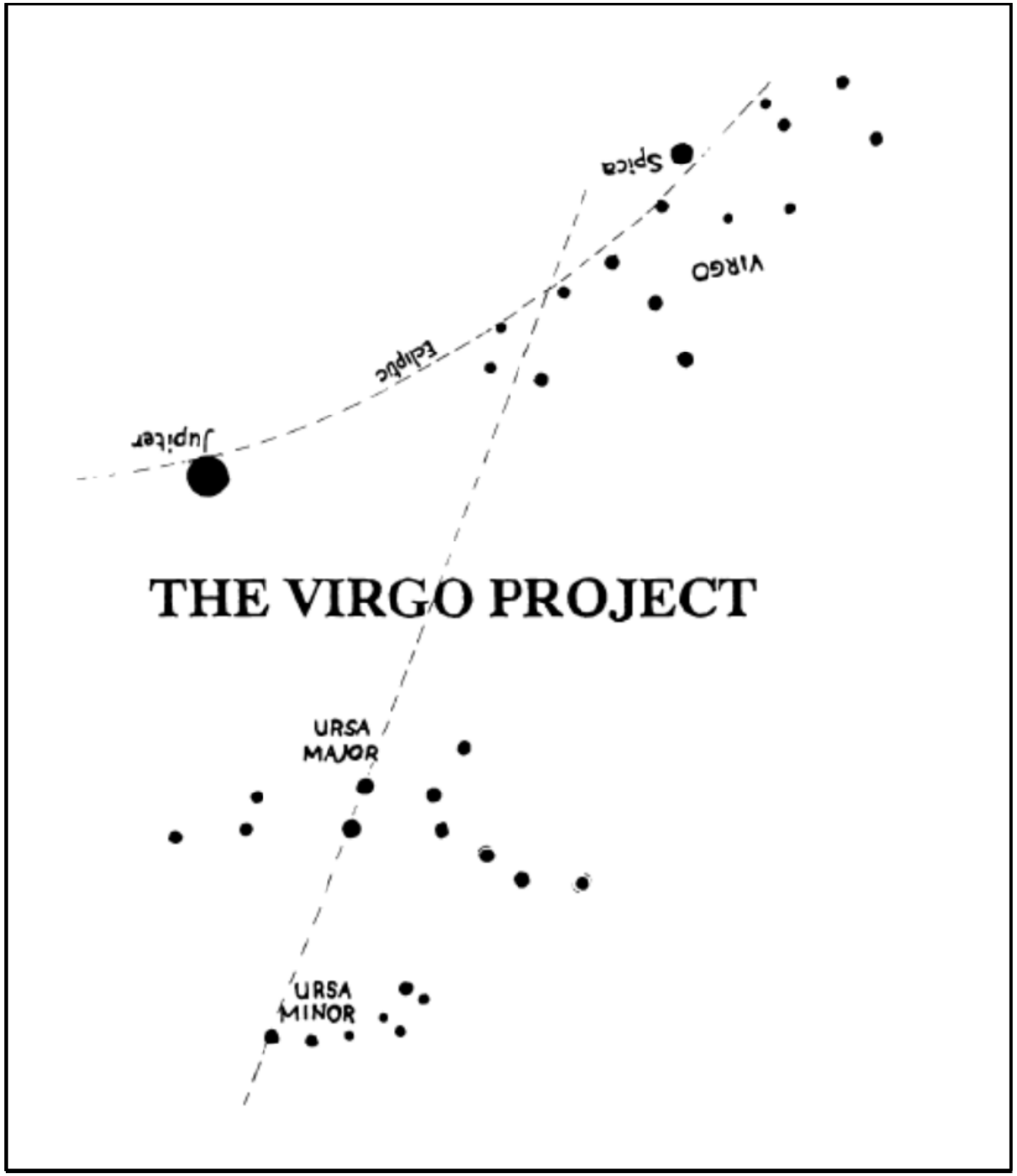
Research Groups: Garching (**Billing**), Malibù (**Forward**), MIT (**Weiss**), Glasgow (**Drever**)

Yellow turned Blue: Explorer at CERN (moved in 1980)

EXPLORER: cylindrical aluminum (Al5056) bar of 2300 kg, 3 m long, diameter of 60 cm. Cooled through helium down to 2.6 K. Resonant frequencies: 906 Hz and 923 Hz. **The first antenna reaching the nominal sensitivity and stability over long periods (1990).**

The choice of cryogenic resonant bars Versus the interferometric detectors had some influence on the future collaborations and steps

1989: The Virgo Project



New international groups joining the endeavour:

- CNRS – Université Paris 6
- Observatoire de Meudon
- University of Illinois
- University of San Paolo

La prima pulsar

Observation of a Rapidly Pulsating Radio Source

by

A. HEWISH
S. J. BELL
J. D. H. PILKINGTON
P. F. SCOTT
R. A. COLLINS

Mullard Radio Astronomy Observatory,
Cavendish Laboratory,
University of Cambridge

Unusual signals from pulsating radio sources have been recorded at the Mullard Radio Astronomy Observatory. The radiation seems to come from local objects within the galaxy, and may be associated with oscillations of white dwarf or neutron stars.

IN July 1967, a large radio telescope operating at a frequency of 81·5 MHz was brought into use at the Mullard Radio Astronomy Observatory. This instrument was designed to investigate the angular structure of compact radio sources by observing the scintillation caused by the irregular structure of the interplanetary medium[1]. The initial survey includes the whole sky in the declination range $-08° < \delta < 44°$ and this area is scanned once a week. A large fraction of the sky is thus under regular surveillance. Soon after the instrument was brought into operation it was noticed that signals which appeared at first to be weak sporadic interference were repeatedly observed at a fixed declination and right ascension; this result showed that the source could not be terrestrial in origin.

Jocelyn Bell, davanti al Mullard Radio Astronomy Observatory (Univ. Cambridge), 1968

Hewish, A., Bell, S. J., Pilkington, J. D. H., Scott, P. F., Collins, R. A., Observation of a Rapidly Pulsating Radio Source, Nature 217, 709-713, 1968