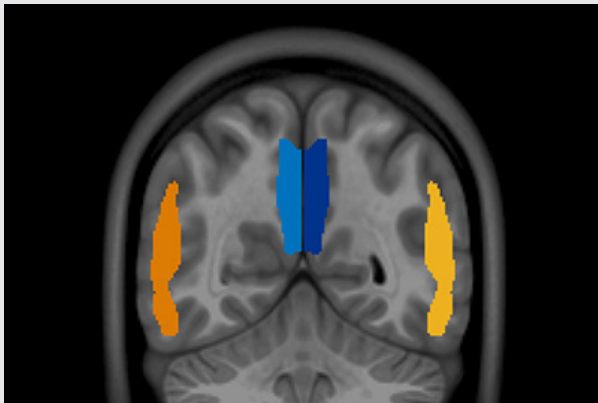


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FROM THE STUDY OF GRAVITATIONAL WAVES A DIAGNOSTIC PROTOCOL FOR ALZHEIMER'S DISEASE

The medical diagnostic protocol developed as a result of the nextMR project is currently in the trial stage at Genoa hospital and is an example of how expertise developed in basic physics research can be directly of use in medical diagnostics. Its primary objectives include the early diagnosis of Alzheimer's disease and, more generally, medical diagnosis in the fields of neurology and oncology. The nextMR project is working on the direct application of data analysis, a key feature of physics research in terms of human and computing resources. At all levels, from high-energy physics to the search for dark matter and gravitational waves, researchers have had to develop increasingly sophisticated measurement systems capable of extracting signals from background noise, and create adequate computing resources. Starting from this potential, about ten years ago a team of physicists at the Genoa division of the INFN set about developing methods and systems for analysing clinical data, using processing techniques already used to some extent in basic research, but which required substantial adaptation before they could be used in medicine.

The aim is identical to that of basic physics research and consists in obtaining a measurement by extracting a signal from the noise, i.e. distinguishing the pathology from "normality". However, with medical data, the "background noise" depends on the individual patient's clinical history and specific characteristics and not on particle which are made up of identical "subjects", as it is in physics. The data set has very different statistical characteristics from those used in physics and the fact that they are extremely variable and cannot be characterised a priori must be taken into account. In this type of context, many hypotheses applicable to physics have fallen apart and had to be adapted or completely reviewed. The nextMR group in Genoa has experience in "ordinary" basic research in the field of gravitational waves, an area that has unexpectedly turned out to be very similar to that of the diagnosis of degenerative diseases. As in the case of medical diagnostics, to detect the signal of a gravitational wave in a data set, you must know the characteristics of the potential signal and "enter" it

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in the data set to check for any similarities. There are many possible signal templates, and the data of a large part of them have to be compared. The problem with diagnosing degenerative diseases is very similar: the disease leaves a sort of signature in the neuro-images of the affected part, an anomaly that can be detected after comparing the image with numerous possible "signatures".

Improved diagnostics will allow medicine to shift more quickly towards preventive treatment, i.e., making it possible to predict the probable course of the disease and so provide more effective treatment, well before the symptoms become evident. This is especially true for Alzheimer's disease, which starts about 15-20 years before the first symptoms appear, and results in increasingly irreversible damage to the brain until - at the onset of the first symptoms - it is no longer possible to stop the progression of the disease and the effects can only be mildly controlled.

Another aspect not to be overlooked and that is essential for successful data analysis is computation. Given the need to handle huge amounts of data, cutting-edge distributed computing systems and highly advanced programming tools have been developed for use in basic physics research. It is thanks to these that discoveries such as the Higgs boson or gravitational waves have been made simply by using highly complex algorithms and extremely powerful computing resources. These data processing capabilities are an extremely valuable resource for medical diagnostics.

One branch of the research activity under the nextMR project is about to enter the clinical application phase. The verification of the analysis technique has already been published and it is now undergoing clinical validation at Genoa hospital. The protocol provides that the ultimate diagnosis, by the hospital and physician, is supported by physicists who provide an imaging data report - obtained through the combined use of innovative positron emission tomography (PET) technology and magnetic resonance (MR) data - giving physicians quantitative information about the regions of the brain most affected.

The entire methodology is the result of close cooperation with physicians and has led to the creation of an interdisciplinary working group of a type rarely seen before in the history of physics and medicine. The entire nextMR project - which follows on from the previous stage called MIND (Medical Imaging for Neurodegenerative Diseases) - is the result of a collaboration between the INFN, specifically the Trieste, Genoa, Pisa, Cagliari, Bari, Catania, L'Aquila and Bologna divisions, the Imago7 consortium in Pisa, the EADC (European Alzheimer's Disease Consortium), the hospitals of Pisa, Genoa, Catania and Trieste and the Recas data centre. ■