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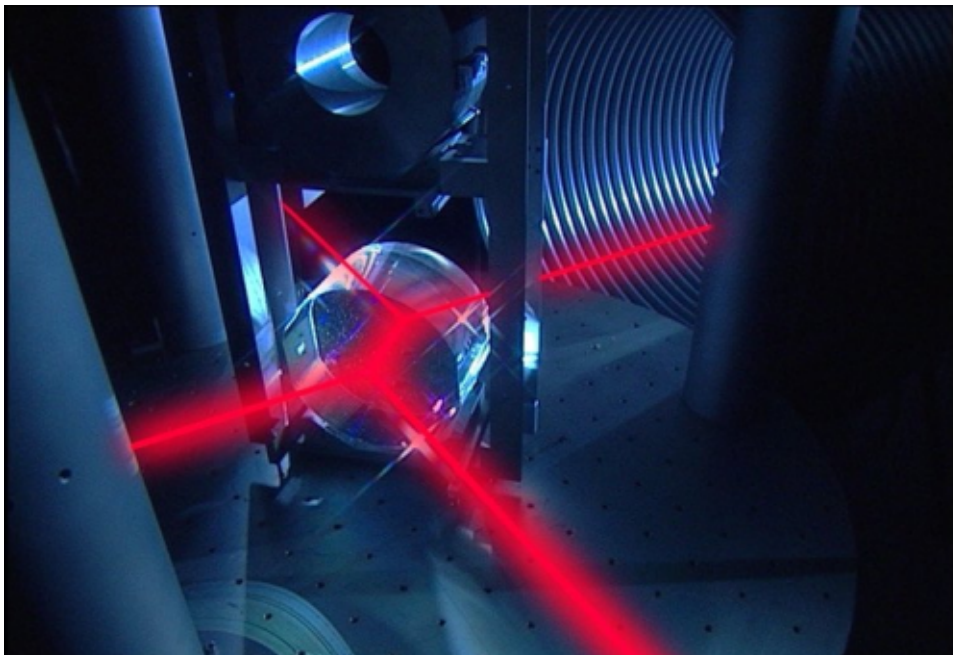


Outreach project for Sonderforschungsbereich/ Transregio 7 "Gravitational wave astronomy"

This outreach project is funded by the Deutsche Forschungsgemeinschaft (DFG) to continuously present the topic of gravitational wave astronomy and the research done by the institutions involved in SFB/TR 7: The universities in Jena, Tübingen, and Hannover, and the Max-Planck-Institutes in Golm, Hannover, and Garching. We attempt to achieve this goal by organizing public events at some of the sites involved, by creating and operating a mobile exhibition showcasing relativity and gravitational wave research, called the "Einstein-Wellen-Mobil", and through a web presence aimed at the general public. The "Einstein-Wellen-Mobil" features interactive experiments, movie stations, and other exhibits, offering the possibility of an active learning experience in the field of gravitational wave research.

During 2009 until the summer of 2010 work focussed on setting up the "Einstein-Wellen-Mobil" as well as a supporting web page. Once completed to some extent, the exhibition visited schools, planetaria, astronomy fairs, and the universities in Jena and Tübingen. Several public events focussing on the topic of gravitational wave astronomy were hosted in Jena and in Tübingen.

The "Einstein-Wellen-Mobil" is designed to allow visitors to not only receive information in a passive fashion, but to become active themselves in many ways. Detailed descriptions of all exhibits can be found on the web page www.einsteinwelle.de or in the corresponding press folder.

All activities in this project make a strong effort to be entertaining as well as to offer substantial information. The intention is to attract visitors by offering them a pleasant experience, giving them the option to leave it at that, or to obtain more information to a considerable depth if their curiosity has been raised.

Part 1: Summary

List of all outreach activities

2009

The "Einstein-Wellen-Mobil" at the planetarium in Mannheim	**26.03.-18.06.**
	21.06.-12.07. Tübingen: Inauguration and presentation of the "Einstein-Wellen-Mobil'
The "Einstein-Wellen-Mobil" at the Mönchsee-Gymnasium in Heilbronn	**16.07.**
	18. 07. The "Einstein-Wellen-Mobil" participates in the open lab day at the department of astronomy and astrophysics, Tübingen
The "Einstein-Wellen-Mobil" on exhibit at the Friedrich-Schiller-Universität, Jena	**25.08.-17.09.**
	16.09. Einstein day for high school students and teachers at the Friedrich-Schiller-Universität, Jena
The "Einstein-Wellen-Mobil" available at the public observatory and planetarium in Rodewisch	**18.09.-08.10.**
	26.09. The "Einstein-Wellen-Mobil" shown at the astronomy fair AME2009 in Villingen-Schwenningen
The "Einstein-Wellen-Mobil" visits the Edith-Stein-Gymnasium, Bretten	**09.10.-23.10.**
	13.11. The "Einstein-Wellen-Mobil" participates in the "Lange Nacht der Wissenschaft", Friedrich-Schiller-Universität Jena
The "Einstein-Wellen-Mobil" visits the Schiller-Gymnasium, Heidenheim	**16.11.-27.11.**
	30.11.-11.12. The "Einstein-Wellen-Mobil" at the public observatory and planetarium in Suhl

List of all outreach activities

2010

12.02.	"Science meets theatre --- Kepler and beyond" Tübingen
15.03.-29.03.	The "Einstein-Wellen-Mobil" visits the Evangelisches Gymnasium, Neuruppin
26.04.-08.05.	The "Einstein-Wellen-Mobil" visits the Kepler-Gymnasium, Reutlingen
17.05.-21.05.	The "Einstein-Wellen-Mobil" visits the Dietrich-Bonhoeffer-Gymnasium, Filderstadt
18.09.	The "Einstein-Wellen-Mobil" on display at the astronomy fair AME2010 in Villingen-Schwenningen

2010 (planned)

15.10. -- 12.11.	The "Einstein-Wellen-Mobil" available at the public observatory and planetarium in Herzberg
Nov. -- Dec.	The "Einstein-Wellen-Mobil" shown at the planetarium in Mannheim

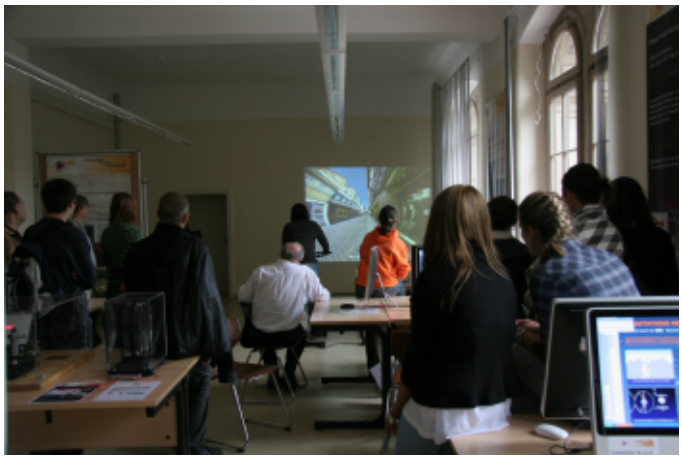
2011 (planned)

17.01. -- 28.01.	The "Einstein-Wellen-Mobil" at the Käthe-Kollwitz-Gymnasium in Lengenfeld
14.02. -- 11.03.	The "Einstein-Wellen-Mobil" featured at the "Urania", Berlin
17.05. -- 17.06.	The "Einstein-Wellen-Mobil" shown at the planetarium in Stuttgart

Part 2: Some typical events

Einstein day for high school students and teachers at the Friedrich-Schiller-Universität, Jena

High school students and teachers were invited to the "Friedrich-Schiller-Universität in Jena for a day of lectures and workshops. About 300 participants learned how the laws of orbital mechanics are significant not only for classical astronomy, but for studying black holes and gravitational waves as well. In the morning, scientists delivered presentations about black holes, neutron stars, and gravitational waves. In the afternoon, workshops introduced current research tasks and offered students the opportunity to try their hands at them:



Measuring the velocity of neutron stars as they move through our galaxy, or analyzing the orbits of stars which orbit very closely to the supermassive black hole in the center of our galaxy.

The "Einstein-Wellen-Mobil" was also available for students and teachers to experience first-hand some of the surprising effects of relativity, and to explore the world of gravitational waves and the techniques used for chasing them.

The Einsteintag was featured on the statewide TV network MDR Thüringen.

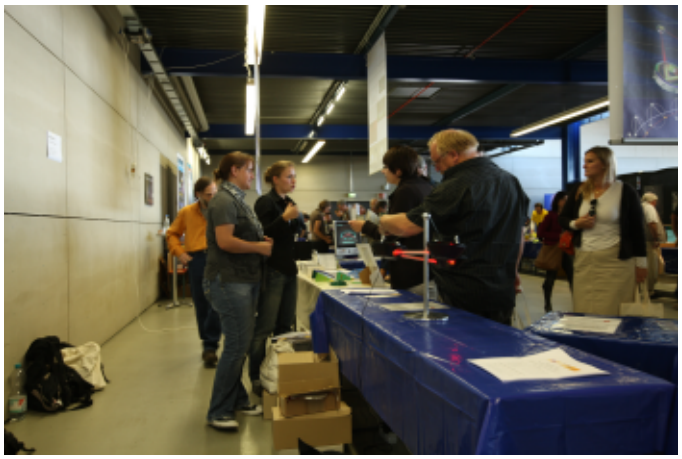
The "Einstein-Wellen-Mobil" available at the public observatory and planetarium in Rodewisch

The public observatory and planetarium in Rodewisch is open for everybody interested in astronomy and science. In particular, they have a strong focus on working with schools in the area, offering students the opportunity to learn about astronomy and to try fundamental observational techniques for themselves. During the three-week stay of the "Einstein-Wellen-Mobil", almost 30 school classes enjoyed experiencing the world of relativity and gravitational waves. The exhibition was complemented by a planetarium show about relativity.

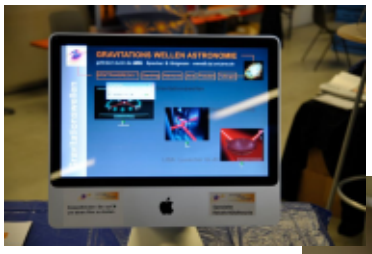
Several newspapers carried articles about this event.

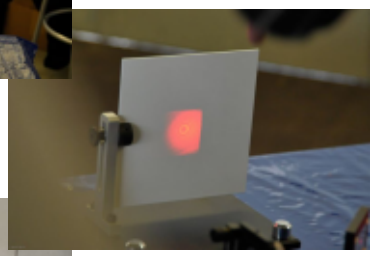
The "Einstein-Wellen-Mobil" shown at the astronomy fair AME2009 in Villingen-Schwenningen

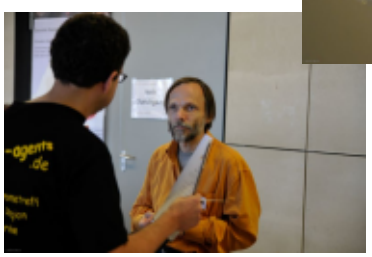
Every year the international astronomy fair in Villingen-Schwenningen attracts a large crowd of professional suppliers of optical instruments as well as amateur astronomers and associations. Held for the fourth time in 2009 it attracted more than 3000 visitors. It is noted for offering an attractive program of scientific presentations as part of the fair. In this environment the "Einstein-Wellen-Mobil" could demonstrate the potential of gravitational research as an innovative branch of astronomy.



Visitors had the opportunity to take a multiple-choice quiz about relativity and gravitational wave astronomy. All answers could be found by studying the various exhibits. Prizes were awarded to those who answered most questions correctly, such as DVDs or literature on relativity and gravitational waves.







"Science meets theatre --- Kepler and beyond", Tübingen

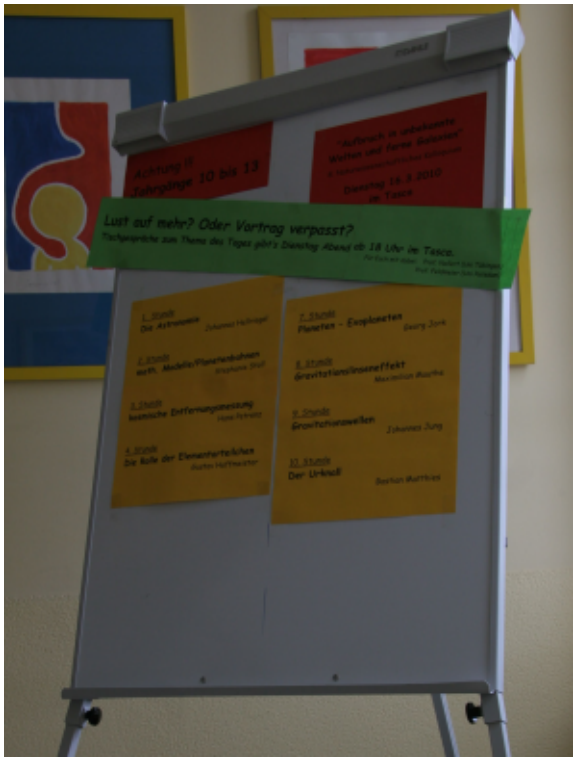
Science meets theatre, alien scientists meet human astrophysics experts, Kepler's pioneer work meets gravitational wave astronomy. Three scientific talks about modern astronomy and gravitational wave astronomy, delivered by Hanns Ruder, Harald Lesch, and Karsten Danzmann, were embedded in a science-fiction-like theatre play staged by the ensemble "KeplerKonferenz". This novel approach offered scientifc information in a fun way without compromising on the integrity of the scientific content.

The "Einstein-Wellen-Mobil" had been set up next to the auditorium. Before the show, visitors could get themselves into the mood by taking a relativistic bicycle ride or by chasing black holes through gravitational wave signals.

Several radio stations and newspapers covered this event before and after. The whole show was videotaped in professional quality. A video DVD will be distributed by KomplettMedia Verlag, a publisher specializing in scientific literature and other material accessible to the general public.

The "Einstein-Wellen-Mobil" visits the Evangelisches Gymnasium, Neuruppin

The science colloquium is already a kind of tradition at the Evangelisches Gymnasium in Neuruppin: Advanced students present selected topics to their peers, in much the same way as it happens at science conferences. This year, the topic was "Unknown worlds and distant galaxies", with talks about the big bang, extrasolar planets, gravitational waves, an many other fascinating subjects.



At this occasion, the "Einstein-Wellen-Mobil" provided an additional attraction and an opportunity to learn about gravitational wave astronomy. Students of physics courses were given an introduction to enable them to present the exhibition to their fellow students and to the general public, to a total of about 500 visitors during the two weeks following the science colloquium.

Part 3: Descriptions of all activities

The "Einstein-Wellen-Mobil" at the planetarium in Mannheim, 26. 03. - 18. 06. 2009

As a kind of preview and test run, the mobile exhibition, though not entirely complete yet, visited the planetarium in Mannheim. The exhibition was available to everybody who visited a show in the planetarium, altogether about 30000 people. The yearly meeting of the association of German-speaking planetaria took place at the Mannheim planetarium from 16.05. to 18.05. We gave a presentation on gravitational wave astronomy and offered special tours of the exhibition at the meeting. Several directors of other planetaria and public observatories who attended the presentation later requested the "Einstein-Wellen-Mobil" for their institutions.

More documents in folder Mannheim/ on the companion DVD.

Inauguration and presentation of the Einstein-Wellen-Mobil, Tübingen, 21. 06. - 12. 07. 2009

Setting up and opening the exhibition for the public marked the "official" inauguration of the "Einstein-Wellen-Mobil" and the start of it going on the road. Many teachers who had been invited by mailings to the schools took the opportunity to make a reservation for the "Einstein-Wellen-Mobil" to visit their schools. While the exhibition was open, about a dozen high school classes from the larger area --- and as far away as Stuttgart --- came to visit, receive an introduction to gravitational wave astronomy, and use the exhibits. They covered a range in age from fourth to twelfth grade.

More documents in folder ExhibitTue/ on the companion DVD.

The "Einstein-Wellen-Mobil" at the topical focus day of the Mönchsee-Gymnasium in Heilbronn, 16. 07. 2009

No images or other documents available.

The "Einstein-Wellen-Mobil" participates in the open lab day at the department of astronomy and astrophysics, Tübingen, 18. 07.2009

At the open lab day offered by the department of astronomy and astrophysics in Tübingen, the "Einstein-Wellen-Mobil" participated as one of many attractions. About 250 visitors passed through offices and labs and took the opportunity to ask questions about relativity and gravitational waves.

Images in folder OpenLabTue/ on the companion DVD.

The "Einstein-Wellen-Mobil" is shown at the Friedrich-Schiller-Universität in Jena, 25. 08. - 17. 09. 2009

The mobile exhibition was set up in two university buildings, one of them very centrally located, directly adjacent to a large shopping center. As an additional eye catcher, the large-scale model of one LISA spacecraft was obtained on loan from the Albert Einstein Institute in Hannover. Graduate students and staff from the department of theoretical physics were available to answer visitors' questions. Several hundred passers-by took a few minutes, some of them quite a few more minutes, to check out the exhibits.

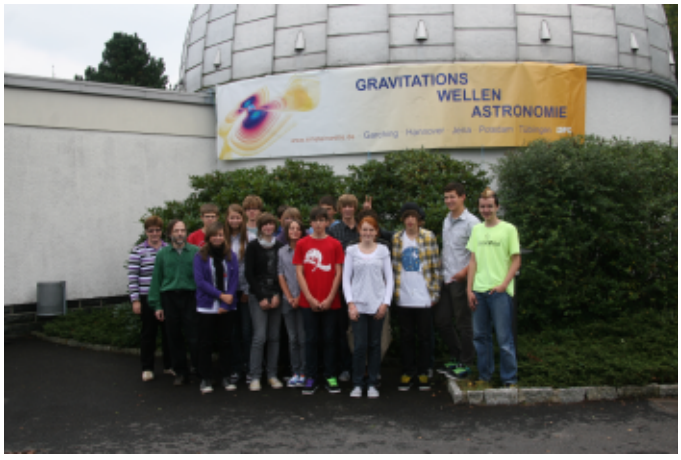
More documents in folder ExhibitJena/ on the companion DVD.

Einstein day for high school students and teachers, Friedrich-Schiller-Universität Jena, 16. 09. 2009

High school students and teachers were invited to the Friedrich-Schiller-Universität in Jena for a day of lectures and workshops. About 300 participants learned how the laws of orbital mechanics are significant not only for classical astronomy, but for studying black holes and gravitational waves as well. The "Einstein-Wellen-Mobil" was also available for active work with the exhibits.

More documents in folder EinsteinJena/ on the companion DVD.

The "Einstein-Wellen-Mobil" set up at the public observatory and planetarium in Rodewisch, 18. 09. - 08. 10. 2009

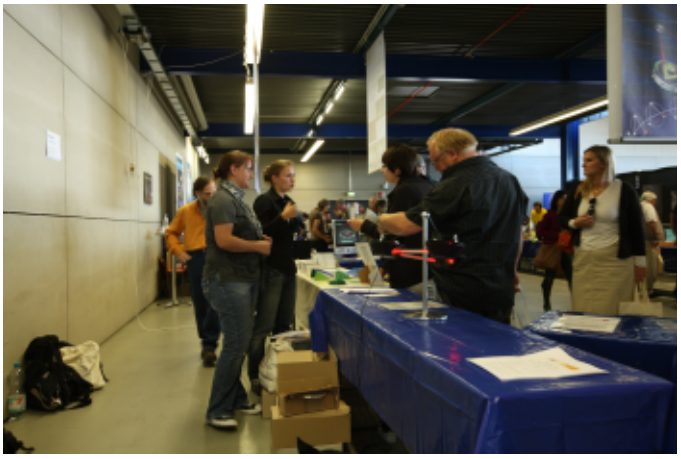


In addition to inviting everybody interested in astronomy and science, the public observatory and planetarium in Rodewisch has a strong focus on working with schools in the area. During this three-week stay at the planetarium, almost 30 school classes took the opportunity to work with the "Einstein-Wellen-Mobil" in combination with a planetarium show about relativity.

More documents in folder Rodewisch/ on the companion DVD.

The "Einstein-Wellen-Mobil" on display at the astronomy fair AME2009 Villingen-Schwenningen 26. 09. 2009

Every year the astronomy fair in Villingen-Schwenningen attracts a large crowd of amateur astronomers and others interested in astronomy. It is noted for offering an attractive program of scientific presentations as part of the fair. In this environment the "Einstein-Wellen-Mobil" could demonstrate the potential of gravitational research as an innovative branch of astronomy.



More documents in folder AME2009/ on the companion DVD.

The "Einstein-Wellen-Mobil" visits the Edith-Stein-Gymnasium, Bretten, 09. 10. - 23. 10. 2009

More documents in folder EinsteinJena/ on the companion DVD.

The "Einstein-Wellen-Mobil" participates in the "Lange Nacht der Wissenschaft", FSU Jena, 13. 11. 2009

More inages in folder LangeNachtJena/ on the companion DVD.

The "Einstein-Wellen-Mobil" visits the Schiller-Gymnasium, Heidenheim, 16. 11. - 27. 11. 2009

Eltern-Info

Radfahren mit Lichtgeschwindigkeit

Wie sieht die Tübinger Altstadt aus, wenn man sie mit nahezu Lichtgeschwindigkeit durchfährt? Das war nur eines von vielen Experimenten, das im Rahmen des Einstein-Wellenmobils 2 Wochen lang am SG gastierte.

Spät abends am Montag, dem 16.November 2009, wurde die mobile Ausstellung „Einstein-Wellen-Mobil" in unserer Schule aufgebaut. Diese Ausstellung, ein Bestandteil des Projekts „Öffentlichkeitsarbeit" im Sonderforschungsbereich/Transregio „Gravitationswellenastronomie" unter Mitarbeit der Universitäten und Max-Planck-Institute aus Jena, Tübingen, Hannover, Garching und Potsdam, will Grundlagen von Relativitätstheorie, Astronomie, Lasertechnik, Raumfahrt und Computeralgorithmen zur Datenauswertung ohne mathematischen Ballast vermitteln. Dies geschieht durch Computersimulationen, Filme und viele Mitmach-Exponate, die den Schülern die Welt der komplexen Wissenschaft und der hochgezüchteten Technologie zugänglich und erlebbar machen. So standen also 8 Power-PCs, ein Michelson-Interferometer, LISA (im Bild unten rechts), eine große Holzkugel, ein Projektor und ein Fahrrad in Zimmer 057 bereit, von den Schülern aus dem SG und den eingeladenen Schülern und Kollegen aus den umliegenden Gymnasien besucht und ausprobiert zu werden.

Höhepunkt der Ausstellung war nach einhelliger Meinung aller Besucher das „Relativistische Fahrrad" (s. Bild). Hier erfahren die Kinder: Die Welt sieht im Rahmen der Relativitätstheorie anders aus als gewohnt. Die Veränderungen, die die begrenzte Lichtgeschwindigkeit auf das Bild einer Szene hat, können erfahren und nachvollzogen werden. An der Leinwand sehen die Schüler, wie die Welt aussieht, wenn man sich nahe Lichtgeschwindigkeit bewegt.

An weiteren Stationen konnte man nach schwarzen Löchern suchen, etwas über Längenkontraktion und Zeitdilatation erfahren, die Geometrie auf einer Kugel ausmessen (im gekrümmten Raum ist die Winkelsumme eines Dreiecks nicht 180°) und viel über Gravitationswellen sehen und hören. Ein abschließender Fragebogen diente zur Festigung des Gelernten.

Nach ca. zwei Wochen war der Spaß dann vorbei und die Ausstellung wurde wieder abgeholt.

Wir bedanken uns noch bei Herrn Prof. Nollert, der extra für eine Einführung der Stationen von Tübingen an unsere Schule kam und geduldig alle Fragen der anwesenden Lehrer (nicht nur Physik-Lehrer!) beantwortet hat. Weitere Informationen sind unter http://www.tat.physik.uni-tuebingen.de/~nollert/EWM/index.html zu erhalten.

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The article on the left about the "Einstein-Wellen-Mobil" at the Schiller-Gymnasium in Heidenheim appeared in the parents' newsletter of the school.

Article in folder Heidenheim/ on the companion DVD.

The "Einstein-Wellen-Mobil" set up at the public observatory and planetarium in Suhl, 30. 11. - 11. 12. 2009

Similar to Rodewisch, the public observatory and planetarium in Suhl invites schools for shows and workshops. They also used the novelty of the "Einstein-Wellen-Mobil" as an opportunity to attract several hundred visitors, many of whom do not usually visit their facilities.

More documents in folder Suhl/ on the companion DVD.

"Science meets theatre --- Kepler and beyond", Tübingen, 12. 02. 2010

Science meets theatre, alien scientists meet human astrophysics experts, Kepler's pioneer work meets gravitational wave astronomy. Three scientific talks about modern astronomy and gravitational wave astronomy were embedded in a science-fiction-like theatre play. This novel approach offered scientifc information in a fun way without compromising on the integrity of the scientific content.

More documents in folder Interstellar/ on the companion DVD, including a short documentary about the show. A DVD containing the recording of the complete show is available on request.

The "Einstein-Wellen-Mobil" visits the Evangelisches Gymnasium, Neuruppin, 15. 03. -- 29. 03. 2010

More documents in folder Neuruppin/ on the companion DVD.

A yearly physics colloquium where students give presentations to their peers on selected topics is already a kind of tradition at the Evangelisches Gymnasium in Neuruppin. With cosmology being the main topic this year, the "Einstein-Wellen-Mobil" provided an additional opportunity to learn about gravitational wave astronomy. Students of physics courses were given an introduction to enable them to present the exhibition to their fellow students and to the general public, to a total of about 500 visitors.

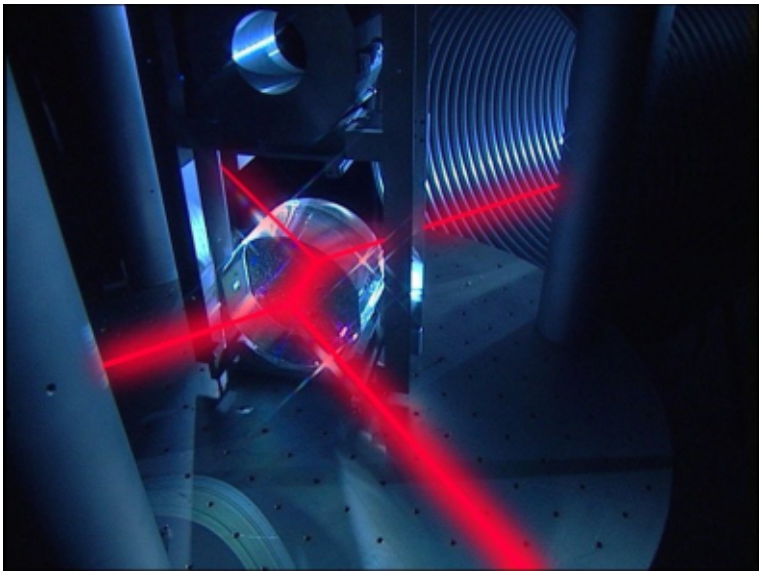
The "Einstein-Wellen-Mobil" visits the Kepler-Gymnasium, Reutlingen, 26. 04. - 08. 05. 2010

No images or other documents available yet.

The "Einstein-Wellen-Mobil" visits the Dietrich-Bonhoeffer-Gymnasium, Filderstadt, 17. 05. - 21. 05. 2010

No images or other documents available yet.

The "Einstein-Wellen-Mobil" -- a mobile exhibition about relativity, gravitational waves, and their detection



The **"Einstein-Wellen-Mobil"** is a major part of the outreach work of the transregional collaborative research centre SFB/TR-7 "Gravitational Wave Astronomy". It is available to schools and other institutions for classroom use, public presentations, or other science-related projects. Topics covered in the exhibition are the theory of special and general relativity, gravitational waves and their detection, use of laser technology, space research, and computer tools needed for data analysis.

All of this is presented without mathematical overhead. Computer simulations, movies, and many interactive exhibits allow visitors to experience the world of complex science and state-of-the-art technology in an intuitive and entertaining way. The exhibits shown on the following pages are just some examples. Please visit the web page of the exhibition at http://www.einsteinwelle.de for a description of all exhibits.

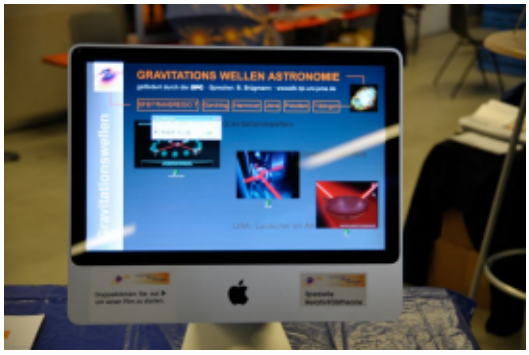
Gravitational wave astronomy picks up where astronomy based on electromagnetic radiation meets its limits. Spectacular cosmic events such as supernovae can be studied down to their inner core, something that is not possible using electromagnetic radiation due to hot gas and debris of the explosion blocking the view. Even the reverberations of the big bang itself, the birth cry of our universe, may be uncovered by gravitational waves. In order to make this possible, theoretical physics, highly developed experimental techniques, astronomy, and computer science have to join forces to overcome the enormous difficulties in detecting and analyzing gravitational waves.

The transregional collaborative research centre SFB/TR-7 "Gravitational Wave Astronomy" is a cooperative effort of mathematicians, theoretical physicists and experimentalists from the universities of Jena, Tübingen, and Hannover, as well as the Max Planck institutes in Potsdam, Hannover, and Garching. Together they study the mathematical basics of the relativistic field equations, develop physical models for the objects which emit gravitational waves, perform numerical simulations, and invent sophisticated algorithms for extracting gravitational wave signals from noise. This transregional collaborative research centre is funded by the Deutsche Forschungsgemeinschaft, it began its work in January 2003.

"Relativistic bicycle ride": Interactive simulation

What would the world look like if we could travel at a speed near that of light? A sight nobody has ever seen, and none of us will. In our virtual world, we can reduce the speed of lgiht to a mere 30 kilometres per hour. Now we can ride a bicycle at nearly the speed of light. Some effort is required to pedal fast enough, but the effort will be rewarded: Objects seemingly retreating from you while you try hard to reach them, houses bending away from you, searchlight and Doppler effect are just a few examples of the strange sights that await the dedicated bicyclist.

Movie stations about special relativity, general relativity, and gravitational waves



You do not think you are a genius -- so how could you ever hope to understand the theory of relativity or gravitational waves? Not to worry -- a series of animated movies will guide you, step by step. The mathematics of all equations which form the theory of relativity can be daunting indeed, the basic principles are surprisingly easy to understand. Nature has a few tricks up its sleeve which run counter to our intuition, but once you accept these, the rest just falls into place. You can explore the exciting world of relativity and gravitational waves at your own pace and to the depth you desire.

While simplifying the basics of the theory as much as possible, these movies do not omit or distort important steps needed to gain an understanding. They are true to the principle Einstein stated when he said: "One should simplify everything as much as possible -- but no more!".

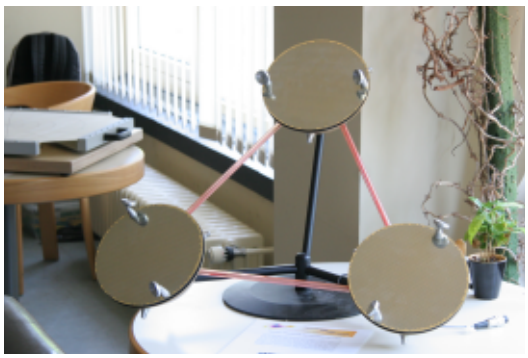
Laser interferometer: Working model

A Michelson interferometer using laser beams is an instrument very well suited to detecting the changes in the geometry of space caused by a gravitational wave. The laser beam is split into two and guided in two perpendicular directions. Mirrors reflect the beams, they are then made to interfere with each other, revealing any changes in distance along the two paths.

This working model is much shorter and immensely less sensitive than the interferometers in actual gravitational wave detectors. Since there is no chance to see the effects of an actual gravitational wave with this model, one of the mirrors can be shifted using a piezo crystal. On the screen the changes in the interference pattern becomes evident while one shifts the mirror by up to 1.5 micrometers.

Orbital configuration of the LISA satellites

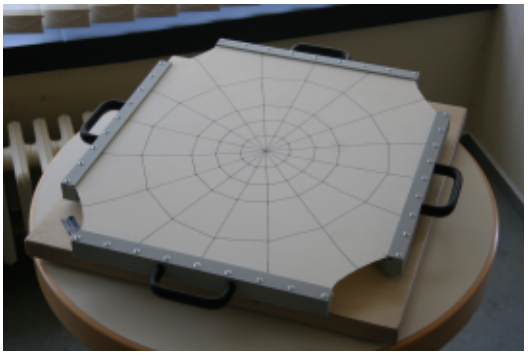
A laser interferometer is more sensitive if it is larger. On earth, arm length is limited to a few kilometres. Therefore a project is under way to deploy a gravitational wave detector in space. LISA (Laser Interferometric Space Antenna) will consist of three satellites with a distance of 5 Million kilometres between them, orbiting the sun 50 Million kilometres away from earth. In addition to having better seinsitivity, LISA will not be subject to seismic noise present on earth. LISA is scheduled to be launched in 2021.

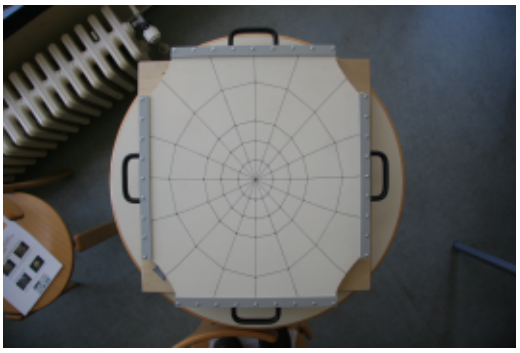


Due to its enormous size, LISA can detect gravitational waves at extremely low frequencies. This will allow the measurement of gravitational waves which originated in the big bang, the birth of our universe.

Placing three satellites in an orbit such that they form a equilateral triangle which does not change its shape while the whole configuration orbits the sun is a major challenge. This model illustrates how this goal can be achieved.

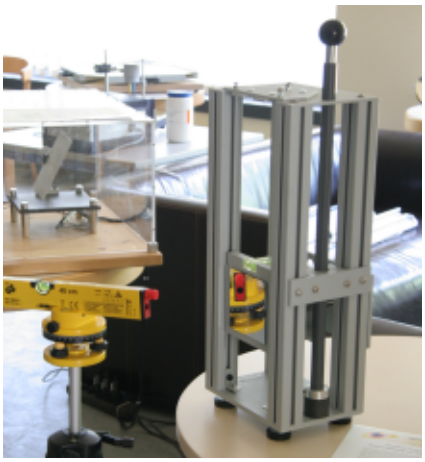
The effect of gravitational waves: An interactive mechanical model





A gravitational wave distorts the geometry of space. Therefore distant objects may change their distance from each other without actually moving relative to their local surroundings. This seemingly paradox situation is illustrated in this interactive mechanical simulation: A rubber sheet may be distorted in two perpendicular directions. Dots painted on the sheet obviously do not move with respect to their surroundings on the sheet, yet they change their distance from each other because the sheet itself is changing its geometry. With the sheet representing the space surrounding us, the concept of space changing its inner geometry, the consequences thereof, and techniques for measuring such distortions is demonstrated in an intuitively accessible fashion. It thus becomes much easier to develop a mental picture of the effect a gravitational wave has on the space it passes through.

Mirror suspension with eddy current damping: An interactive model



Mirrors in terrestrial gravitational wave detectors must be shielded against seismic noise, i.e. ground movements. This is achieved by suspending them like pendulums, with a sharply defined resonance frequency far from the actual frequency range of the detector. However, the mirrors may then be excited to rather large oscillations at the resonance frequency, making the detector as a whole unstable. To counteract this, the oscillations can be damped using eddy current damping.

This working model demonstrates a suspended mirror equipped with an eddy current damping which can be activated or deactivated by a mechanical lever. A laser beam reflected from the mirror serves to reveal the movements more clearly. The mirror can be made to move in different ways, allowing the observation of the effect of the eddy current damping on the different modes of motion.