Resource Letter GrW-1: Gravitational Waves
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This Resource Letter provides a guide to the literature on the physics and astrophysics of gravitational waves. Journals, books, reports, archives, and websites are provided as basic resources and for current research frontiers in detectors, data analysis, and astrophysical source modeling.

I. INTRODUCTION

The phenomenon of gravitational radiation was one of the first predictions of Einstein's general theory of relativity. Progress in understanding this radiation theoretically was slow at first, owing to the difficulty of the nonlinear field equations and the subtleties of their physical effects. The experimental side of this subject also has taken a long time to develop, with efforts at detection severely challenged by the extreme weakness of the waves impinging on the Earth. However, as the 21st century begins, observations of the gravitational waves from astrophysical sources such as black holes, neutron stars, and stellar collapse are expected to open a new window on the universe. Vigorous experimental programs centered on ground-based detectors are being carried out worldwide, and a space-based detector is in the planning stages. On the theoretical side, much effort is being expended to produce robust models of the astrophysical sources and accurate calculations of the waveforms they produce. In this Resource Letter, a set of basic references will be presented first, to provide a general introduction to and overview of the literature in this field. The focus then will shift to highlighting key resources in more specialized areas at the forefront of current research.

II. BASIC RESOURCES

A. Journals

Most of the important results in gravitational-wave physics and astrophysics are published in the following journals:

- Physical Review D
- Physical Review Letters
- Classical and Quantum Gravity
- Astrophysical Journal
- Astrophysical Journal Letters
- Living Reviews in Relativity (electronic journal: www.livingreviews.org)
- Astronomy and Astrophysics
- Monthly Notices of the Royal Astronomical Society
- Review of Scientific Instruments
- Measurement Science and Technology
- Journal of Physics E
- Journal of the Optical Society of America
- Physics Letters A
- Optics Letters
B. Electronic Archives

Most of the important papers in the areas of gravitational-wave theoretical source prediction, measurement theory, and analysis from the mid-1990s onward are posted on one of both of the following e-print archives:

http://lanl.arxiv.org/archive/gr-qc/ This website (abbreviated gr-qc in the references in Secs. III. C-D below) features papers in the areas of general relativity and quantum cosmology.
http://lanl.arxiv.org/archive/astro-ph/ This website (abbreviated astro-ph in the references in Secs. III. C-D below) has papers in the general category of astrophysics.

The LIGO Document Control Center is a repository of experimental papers, mainly focused on LIGO: http://admdbsrv.ligo.caltech.edu/dcc/. The VIRGO project maintains a bibliography of articles from roughly 1990 – 1999 at the website http://www.pg.infn.it/virgo/local/biblio.htm in the following four categories: gravitational-wave theory and experiment, data analysis in gravitational-wave detectors, internal friction and thermal noise, creep and acoustical emissions.

In addition, the NASA Astrophysics Data System provides, without charge, the ability to search the abstracts and access the full text of many of the relevant papers and journals in which research on gravitational waves is published: see http://adswww.harvard.edu/.

C. Conference Proceedings

Researchers in gravitational-wave physics and astrophysics depend heavily on conferences and their proceedings for the dissemination of new results. A representative sampling of recent proceedings volumes is given below.

1. Proceedings of the 4th Edoardo Amaldi Conference on Gravitational Waves, Classical and Quantum Gravity 19, 1227 – 2049 (2002). This special issue, available freely at the journal’s website (http://www.iop.org/EJ/S/UNREG/nB8zy.1HfQeoB8FLR2b4A/toc/0264-9381/19/7 ) is edited by David Blair. (A)
4. Proceedings of the 3rd International LISA Symposium, Classical and Quantum Gravity 18, 3965-4164 (2001). This special issue is edited by Bernard Schutz. (A)
5. Gravitational Waves: A Challenge to Theoretical Physics, edited by V. Ferrari, J. Miller, and L. Rezzolla (Abdus Salam International Centre for Theoretical Physics, Trieste, 2001). (A)

D. Textbooks and Expositions

2
The topic of gravitational waves is usually introduced as part of a course in general relativity. The following is a representative sample of useful textbooks. The first two books are at the level of advanced undergraduates or beginning graduate students. The book by Stephani is at the introductory graduate level.


The next four books are at the level of advanced graduate students. Although they were originally published roughly 20 - 30 years ago, they remain standard texts and references for both students and researchers. Readers should be aware that much of the astrophysical material in the applications in these references is now out of date.


There also are a number of useful expositions on gravitational waves, at a variety of levels. The first two books are accessible to general readers, and also provide overviews and perspectives of interest to more specialized researchers. The third book presents an introduction to gravitational-wave detectors at the advanced undergraduate level and above.


**E. Websites**

The AstroGravS website contains a catalog of computed gravitational waveforms that can be downloaded, as well as useful information on astrophysical sources and links to the literature.


The following websites are maintained by various ground-based gravitational-wave detection efforts; such detectors will be sensitive to high-frequency gravitational waves, roughly 10 – 1000 Hz.

18. [http://www.ligo.caltech.edu](http://www.ligo.caltech.edu) This is the website for the US LIGO project.
19. [http://www.geo600.uni-hannover.de/](http://www.geo600.uni-hannover.de/) This is the website for the GEO-600 interferometer.
III. Current Research Frontiers

Research on gravitational waves is an active and growing field, encompassing a broad range of work in experimental, theoretical, and computational physics. In this section, several key references in the main areas of activity will be highlighted to provide an entry into the literature.

A. General Articles

The first article is a recent overview at a fairly general level of the growing field of gravitational-wave physics and astrophysics. The second, although published 15 years ago, remains an important general introduction to research in gravitational radiation at a research level; the third is an accessible account of how observations of gravitational waves can be used to test general relativity.


B. Detectors

Much of the current information available on the experimental efforts can be found in articles in the conference proceedings in Sec. II C and at the websites listed in Sec. II E. Some reports of particular interest include the following:

30. http://www.ligo.caltech.edu/~ligo2/ This website and the documents available there detail the plans for the advanced LIGO interferometers.
In addition, the following journal and proceedings articles provide a representative sampling of the literature on detectors:

Gravitational Wave Detection by Interferometry (Ground and Space)
S. Rowan and J. Hough
Living Reviews in Relativity, http://www.livingreviews.org/


C. Astrophysical Sources of Gravitational Waves

The expected sources of gravitational radiation are all astrophysical in nature and comprise some of the most interesting and exotic objects in the universe, such as black holes. The following pair of companion articles presents connections between black holes and gravitational waves, the first from the viewpoint of fundamental physics and the second from astrophysics:


Inspiralling compact binaries constitute one of the most important classes of gravitational-wave sources. When the binary components are neutron stars and/or stellar black holes, the gravitational radiation emitted towards the end of the inspiral is in the high frequency range of roughly 10 – 1000 Hz, making the systems targets for ground-based detectors. If the binary components are massive black holes, with
masses in the range of roughly $10^4 - 10^7$ times the mass of the sun, the gravitational waves are of low frequency, roughly $10^4 - 10^5$ Hz, and may be detected by the space-based LISA.

During the early stages of the inspiral, the binary components are widely separated and can be treated as point particles. Post-Newtonian methods have been used to calculate the gravitational waves in this regime for many years; more recently, an effective one-body approach has been used. Some representative papers include:


Once the binary components get close to merger, full numerical simulations are needed to calculate the waveforms. For binary black-hole systems which have no gas or other matter, the waveforms from a calculation can be scaled with the masses and spins of the components to apply equally to stellar black hole systems (producing high-frequency gravitational waves) or massive black hole systems (producing low frequency waves). The following papers highlight some of the recent successes and challenges in the simulation of binary black hole mergers:


If one or more of the binary components are neutron stars, the equations of hydrodynamics also must be solved. Representative papers in current research include:


Compact binaries within the Milky Way Galaxy are an important source of low-frequency gravitational waves for LISA. While some of these galactic binaries should be detectable individually, the gravitational waves from the vast number of such binaries will produce a stochastic background of “noise” for LISA. The following papers discuss this class of sources:

An “extreme-mass-ratio” binary, consisting of a neutron star or stellar black hole inspiralling into a massive black hole at the center of a galaxy, is one of the most interesting sources for LISA. The gravitational radiation produced as the smaller object inspirals into the massive black hole can provide a map of the gravitational potential of this exotic central object. This situation is explored in the following articles:


There is a variety of other sources of gravitational radiation, including the gravitational collapse of stars and supermassive stars, dynamical “bar” instabilities in rapidly rotating stars, crustal deformations of neutron stars, and cosmological gravitational waves. The following list of papers gives a sample of recent work in some of these areas:


D. Gravitational-Wave Data Analysis

The field of gravitational-wave data analysis, although in its infancy, is developing rapidly to meet the needs of the experimental efforts. The resonant-mass detector community has become organized and started exchanging data. The kilometer-scale ground-based interferometers are just beginning to take data. And the consideration of data analysis strategies is playing an important role in the design of LISA.

The conference proceedings listed in Sec. IIC above are a good source of articles on current gravitational-wave data analysis efforts. In addition, the following journal articles provide a representative sampling of the current literature:
65. “Robust statistics for deterministic and stochastic gravitational waves in non-Gaussian noise I: Bayesian analyses,” B. Allen, et al., gr-qc/0205015. (A)