

University of Groningen

## Gravity's Relentless Pull

Marel, R. P. van der; Schaller, D.; Kleijn, G. V.

*Published in:*  
 ArXiv

**IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.**

*Document Version*  
 Early version, also known as pre-print

*Publication date:*  
 2006

[Link to publication in University of Groningen/UMCG research database](#)

*Citation for published version (APA):*

Marel, R. P. V. D., Schaller, D., & Kleijn, G. V. (2006). Gravity's Relentless Pull: An interactive, multimedia website about black holes for Education and Public Outreach. Manuscript submitted for publication. [https://pure.rug.nl/admin/files/14616112/gravitys\\_relentless.pdf](https://pure.rug.nl/admin/files/14616112/gravitys_relentless.pdf)

### Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

### Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

*Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.*

## **Gravity's Relentless Pull: An interactive, multimedia website about black holes for Education and Public Outreach**

Roeland P. van der Marel

*Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218*  
([marel@stsci.edu](mailto:marel@stsci.edu))

David Schaller

*Educational Web Adventures, 1776 Iglehart Avenue, St. Paul, MN 55104*  
([david@eduweb.com](mailto:david@eduweb.com))

Gijs Verdoes Kleijn

*Kapteyn Astronomical Institute, Groningen, 9700 AV, The Netherlands*  
([g.verdoes@astro.rug.nl](mailto:g.verdoes@astro.rug.nl))

### **ABSTRACT**

We have created a website, called "Black Holes: Gravity's Relentless Pull", which explains the physics and astronomy of black holes for a general audience. The site emphasizes user participation and is rich in animations and astronomical imagery. It won the top prize of the 2005 Pirelli INTERNETional Awards competition for the best communication of science and technology using the internet. This article provides a brief overview of the site. The site starts with an opening animation that introduces the basic concept of a black hole. The user is then invited to embark on a journey from a backyard view of the night sky to a personal encounter with a singularity. This journey proceeds through three modules, which allow the user to: find black holes in the night sky; travel to a black hole in an animated starship; and explore a black hole from up close. There are also five "experiments" that allow the user to: create a black hole; orbit around a black hole; weigh a black hole; drop a clock into a black hole; or fall into a black hole. The modules and experiments offer goal-based scenarios tailored for novices and children. The site also contains an encyclopedia of frequently asked questions and a detailed glossary that are targeted more at experts and adults. The overall result is a website where scientific knowledge, learning theory, and fun converge. Despite its focus on black holes, the site also teaches many other concepts of physics, astronomy and scientific thought. The site aims to instill an appreciation for learning and an interest in science, especially in the younger users. It can be used as an aid in teaching introductory astronomy at the undergraduate level.

## 1. Introduction

Some of the Hubble Space Telescope’s most ground-braking discoveries have been about black holes, which are arguably the most extreme and mysterious objects in the universe. As a result, black holes appeal to a general audience in a way that almost no other scientific subject does. Unfortunately, most people have little idea of what black holes actually are, and they are more likely to associate them with science fiction than with science. These circumstances recommend black holes as a natural topic for an education and public outreach (E/PO) activity. To this end, we have created a website called ”Black Holes: Gravity’s Relentless Pull,” which serves as the E/PO component of several Hubble observing projects. The new website is part of HubbleSite, the Internet home of all Hubble news. The URL is <http://hubblesite.org/go/blackholes/> .

Many sites on the internet already explain black holes in one way or other. Most are encyclopedic, offering detailed text and graphics. By contrast, our site emphasizes user participation, and it is rich in animations and audio features. This approach was facilitated by the availability of powerful software for authoring multimedia content. The result is a website where scientific knowledge, learning theory, advanced technology, and pure fun all converge.

## 2. The Website

The opening animation at our website introduces the basic concept of a black hole. It shows how one could turn the Earth into a black hole, if only one could shrink it to the size of a marble. By connecting enigma and commonplace, this scenario lends black holes a seeming familiarity.

The core of the website consists of three sequential, interactive modules, of which ”Finding the Invisible” is the first. It shows the night sky with a viewfinder that can be dragged around to discover images of about a dozen objects, including some that should be familiar to the user (the Sun, Moon, and Saturn) and others that only an astronomer might recognize (Betelgeuse, Crab nebula, Cygnus X-1, Andromeda galaxy, and quasar 3C273). The user can select the wavelength range of the viewfinder: visible light, radio waves, or X-rays. The goal is to teach which types of objects contain black holes and which do not. Interested users can move to pages that explain the various objects, the telescopes used to observe them, and the features in the images at different wavelengths that indicate the presence of a black hole. In this way the user not only learns about black holes, but also about their relation to other objects in the Universe and the methods that astronomers use to study them.

When the user has found one or more black holes, he or she can choose to go to the second module, ”The Voyage,” which offers a multimedia trip in an animated starship to a nearby black hole, either a stellar-mass black hole (Cygnus X-1) or a supermassive black hole (in the center of the Andromeda galaxy). The viewer traverses the Solar System as well as our own Milky Way galaxy. Various intriguing objects are encountered along the way, including many of the objects previously encountered in the first module. A goal is to connect the two-dimensional, projected view of the night sky to the actual three-dimensional structure of the universe. In the process, the user learns about the distance scale and the layout of the local universe.

After the spaceship has arrived at the black hole, the user can proceed to the third module, "Get Up Close." Orbiting around a black hole, the sky outside the spaceship window looks strangely distorted, because of the strong gravitational lensing of distant starlight. The module discusses this and many other fascinating phenomena to be encountered near black holes.

Five interactive experiments are offered to explore specific issues. "Create a Black Hole" allows the user to study the evolution of stars of different masses by trying to create a black hole, rather than a white dwarf or neutron star. "Orbit around a Black Hole" plots relativistically correct orbits around a black hole, showing how it is possible to orbit a black hole without being sucked in. "Weigh a Black Hole" shows how to use observations of a black hole in a binary system to calculate its mass. This illustrates learning without seeing. "Drop a Clock into a Black Hole" explains time dilation and redshift. Mysteriously, an outside observer never sees a falling clock disappear beyond the event horizon, which highlights the principle of relativity. The last experiment, "Fall into a Black Hole" allows the viewer to take the final plunge and witness how one's body gets stretched by tidal forces. With this, the user's journey is complete, from the backyard view of the night sky to a personal encounter with a singularity.

### 3. Learning theory

Our motivations for adopting a strongly interactive website were grounded in specific learning theories, "constructivism" in particular. Constructivism holds that learning is not merely an addition of items into a mental data bank, but rather requires a transformation of concepts in which the learner plays an active role making sense out of a range of phenomena. Research has shown that people use various learning styles to perceive and process information. For these reasons, we structured the scientific content in multiple ways at our website, to engage a range of learners in a variety of meaningful ways.

Novices and children often prefer interactive learning experiences, which can motivate them to stay engaged until they achieve some payoff. The interactive modules and experiments of the black hole website are tailored for this audience. They offer goal-based scenarios, to motivate learning and a sense of accomplishment when completed. By contrast, experts and adults often prefer formal organization and ready access to information that they already know about and just want to locate. To reach this audience, the site also contains an encyclopedia of FAQs — frequently asked questions — about the physics and astronomy of black holes, as well as a detailed glossary.

We are currently working on a modified version of the web site that can be used as a kiosk exhibit in museums, science centers and planetaria. This will further broaden the audience of the project to include those people who do not have access to the Internet, or who typically do not use it to broaden their knowledge.

#### 4. Current Science

The entire site is based on the most recent scientific knowledge. Recent results and ongoing projects are highlighted where possible. We will continue to update the site as new discoveries emerge. Astronomical images from state-of-the-art telescopes are used in abundance, with a particular focus on Hubble. Extensive links are provided to other websites on the Internet, which allows users to explore specific subjects in more detail.

Even with its sharp focus on black holes, our site strives to teach much more. We illustrate how humans can understand the universe by detailed observations of the night sky. We teach basic concepts, like light and gravity. We show how different perspectives can enrich our understanding of nature. We illustrate the many wonders of our universe, and demonstrate its scale by alerting the user to what is really near and what is really far away. And we highlight the many things about black holes — and our universe — that we still do not understand.

In the broadest sense, our goal has been to show that even the most mysterious of things can be understood with the combined application of human thinking and powerful technology. We hope to convey the importance of scientific thought and to instill an appreciation for learning and an interest in science, especially in the younger generation of users.

We are grateful to the many people who assisted with the creation of the website, or who provided graphics, animations, or software. A full list of credits is available at [http://hubblesite.org/discoveries/black\\_holes/credits.html](http://hubblesite.org/discoveries/black_holes/credits.html) . We would also like to thank Bob Brown for editorial assistance with this article.

figure provided as jpeg

Fig. 1.— At the first module, a viewfinder can be moved across the sky to find and collect night sky objects. The objects can be viewed at different wavelengths and a text box indicates whether or not a black hole has been found. The "Learn More" button provides access to a wealth of background information.

figure provided as jpeg

Fig. 2.— At the second module, the user undertakes a trip in an animated starship to a nearby black hole, encountering many intriguing objects along the way. The cockpit dials show the current speed and distance traveled. Here, the traveler has arrived at Cygnus X-1 and witnesses how a stellar-mass black hole accretes mass from its binary companion star.

This figure "fig1.jpg" is available in "jpg" format from:

<http://arXiv.org/ps/astro-ph/0606601>

This figure "fig2.jpg" is available in "jpg" format from:

<http://arXiv.org/ps/astro-ph/0606601>