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# Black Holes And Beyond

## From Hypothesis to Detection

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Front cover: Press Release 1332 of the "European Southern Observatory" ESO from July 2013 © S.Gillessen (MPE). Headline: Fo "New observations from ESO's Very Large Telescope show for the first time a gas cloud being ripped apart by the super-massive black hole at the centre of the galaxy. The cloud is now so stretched that its front part has passed the closest point and is travelling away from the black hole at more than 10 million km/h, whilst the tail is still falling towards it".

The photograph taken at widely separated time intervals, shows how the gas cloud has arrived at the black hole in the centre of the Milky Way. It is the first proof that black holes really do exist, but by its very nature, the black hole itself cannot be seen.

**Werner Brückner, Dipl.Ing. (FH) of Physics,** was born 1950 in Göppingen, South Germany. He studied at the Naturwissenschaftlich Technische Akademie under Prof. Dr. Grübler in Isny, Germany, and is currently working at the Institut für Rundfunktechnik (Radio Technology) in Munich. He is also a member of the public observatory there.

**Annotation:**

This book includes formulae for which some knowledge from a college course, would help but is not essential to enjoy the book. It is for future students of science subjects and also for those simply interested in Astronomy and Astrophysics. It will help a reader to know that this book is specifically an *introduction* to this fascinating subject, with the intention of providing a very wide overview assisted by many illustrations, putting it ahead of similar books but without going too deeply into the details which The Specialist might expect. This keeps the book more readable to the popular science enthusiast who may go on to seek more advanced material.

I have to thank my friend **Howard Murray**, Stockport, England for his translation from my English writings. He enjoyed the work but of course kept the book British concerning the selection of some phrases. American readers surely will forgive this.

# Content

# Foreword

Black holes are amongst the most fascinating subjects in Astrophysics. They are at the centre of research and are of great importance in cosmology. The reader will be informed of the latest state of knowledge at 2013, including the newest discovery of a black hole in the centre of the Milky Way. The book also deals with the history of black holes, beginning with Medieval times when nobody knew of what a star consisted. The breathtaking development in Physics and Astronomy has been so fast that there is now a need for overview and summary.

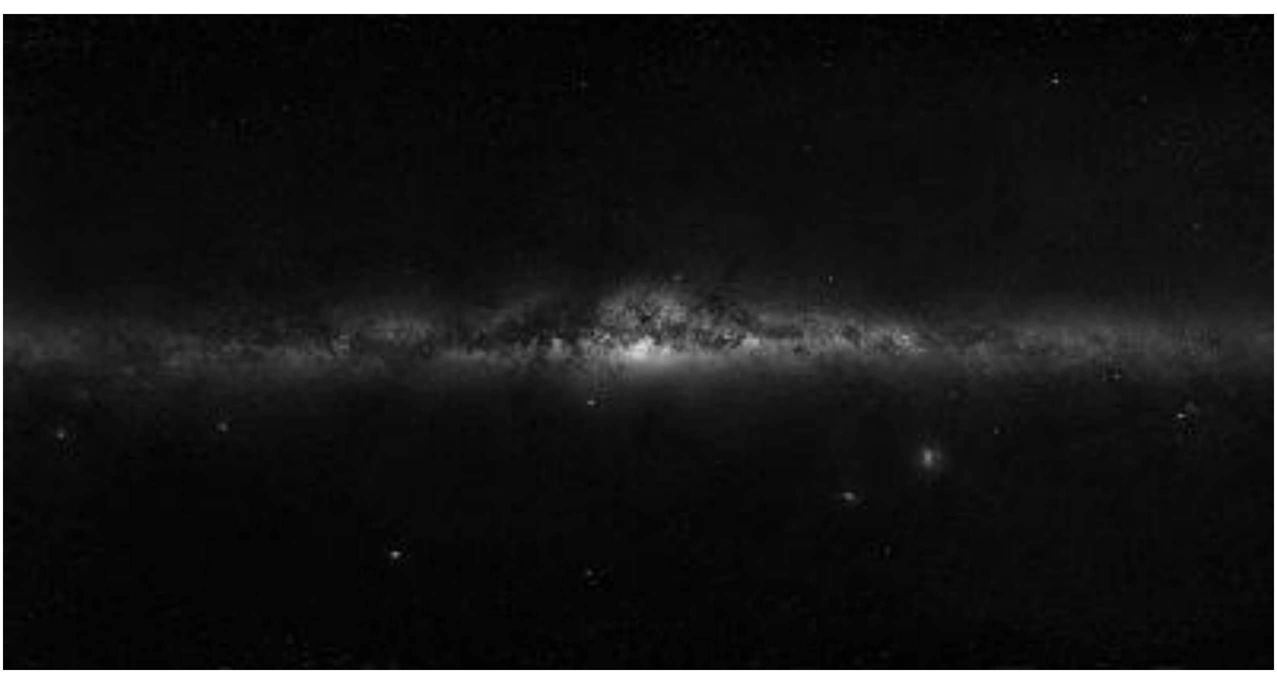
This book is aimed at the reader who is interested in popular science. It is based on facts garnered by highly respected organizations like the ESO, NASA and one of the greatest world wide research institutes, the Max Planck Institute of Science. This book also tries to present complex information in an enjoyable form, achieved with the help of illustrations and graphics which get directly to the point.

The book employs a step by step approach to assist the reader in the under-standing of the complexity of theory regarding black holes. The physics of star formation alone, could justify a separate book. Just as the understanding of the early cosmos is changing steadily, so also is the understanding of black holes.

Related to the issues of black holes, there is further information at the end of the book in the form of a list of internet addresses which might be of interest to the reader.

# Introduction

A Black Hole is a celestial body whose gravitation is so immense that nothing can escape its influence, not even light. As we know now, there are plenty of them. The discovery is surely one of the greatest advances in the last ten years. They were predicted by theory which is a crowning achievement for Mankind. Surprisingly, the history of the discovery goes way back in history. But because they are black they are hard to see and to detect. Since the discovery of a supermassive Black Hole in the centre of the Milky Way, such objects have been discovered in nearly all galaxies. Only now are we beginning to understand just how closely the formation and the destiny of galaxies are influenced by black holes.



*Our Milky Way with the bright centre concealing a Black Hole*

*(By courtesy of the European Southern Observatory, ESO)*

It is possible that human beings could not exist without them. They attract, in a double sense of the word. On one hand they attract matter because of their immense gravity and on the other hand they are attractive to Scientists and non-Scientists alike because of the many secrets which accompany their existence.

They certainly do exist out there in space. They have now entered every day language. Something which disappears and can‘t be found is said to have “disappeared into a black hole“. It is a saying which can be heard in daily speech and has become a euphemism for something which gets lost for ever.

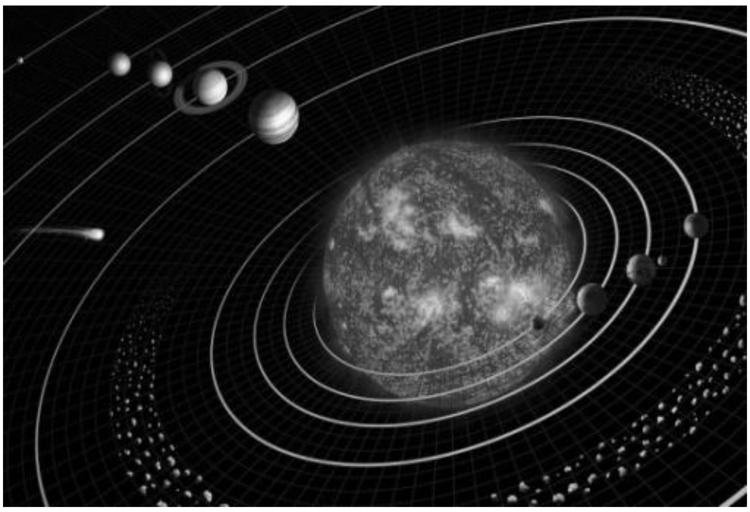
So, to where does all the poor unfortunate prey of a Black Hole go? Victims come in all sizes, sometimes consisting of complete sun systems including their planets and sometimes even whole galaxies are eaten up by the monster, step by step. Black holes are frightening!

Pre-occupation with the subject soon leads us to the fundamental questions of Mankind: Where do we come from? Where are we going?

The Astrophysicist gives some surprising answers. This is now becoming possible because of large-scale projects like the Large Hadron Accelerator in Geneva and by big telescopes like the “Very Large Telescope“ of the ESO in Chile.

# Early History

In the 17th Century, little or nothing was known of the nature of stars or their relationships. Neither was it clear if our Sun was constructed of the same matter as the thousands of other sparkling stars in the night sky. People thought that The Sun contained vast quantities of burning coal. However, when seen through telescopes invented at the end of the 16th century, different colours could be observed. Some stars appeared more red, some more blue, but most were radiating white light. As the consequence of that, it became apparent that all stars were *not* the same. However, the difference in brightness of the stars *was* correctly explained by their unequal distances from Earth. Nobody knew anything about **Black Holes** – the name was yet to be coined. However, the laws of celestial mechanics were already known, owing to the work of one Johannes Kepler, a German astronomer. It was Kepler who had calculated the times of planetary orbits, according to their distances from The Sun. Today this is known as Kepler´s Laws of Planetary Motion. At this time however, the force which held the planets in their orbits of The Sun was still unknown. Obviously there was a secret, long ranging force present.



*The emergence of our planetary system (Artist´s impression, Wiki)*

Suddenly in the 17th Century, appeared the genius **Isaac Newton**, President of the Royal Society in London and Lucasian Professor of Mathematics at the University of Cambridge (as later was the famous Stephen Hawking from 1979 to 2009).

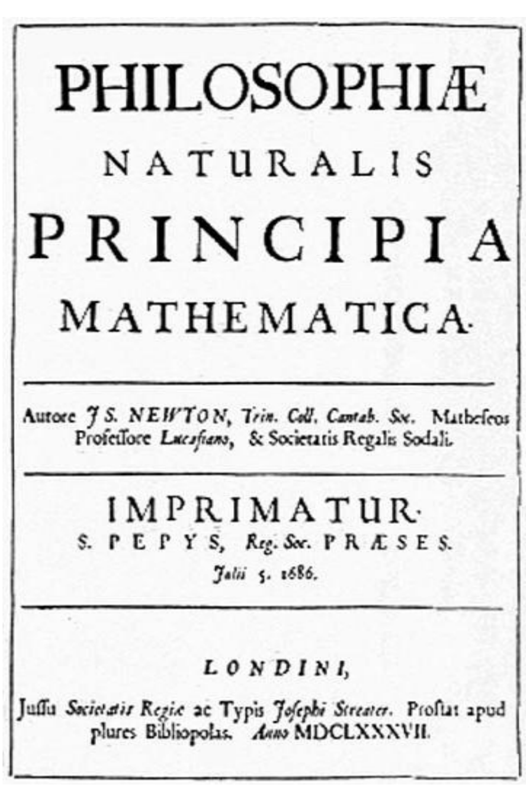
*Sir Isaac Newton, 1632 - 1726, discovers the fundamental laws of mass attraction through gravitation (Wiki)*

Together with Gottfried Leibnitz, Newton is credited as the inventor of Infinitesimal Calculus and he was the first to contemplate the nature of light and the essence of gravity.

The controversial tradition is that it was a falling apple which caused him to think about gravity, whilst sitting under an apple tree. He also invented more practical applications. A telescope using a mirror as a reflector at the back instead of a lens in the front carries his name, The Newtonian Telescope, to this day.

Newton was first to devise a correct interpretation of gravity and to define the Laws of Motion in formulae. He was the one to conclude that it is the Earth which makes the apple fall, by gravitational pull. Conversely, there must also be an influence albeit small, by the apple upon the Earth. Newton had formulated his Laws of Motion already by 1686, describing the relationship between a body or mass and the forces acting upon it. Including Kepler´s laws of planetary motion he was able to formulate a law of Universal gravitation, which is also valid for black holes. Of course these bodies were as yet unknown in Newton’s time, therefore he made no mention of them.

Newton definitely discovered the relationship between mass and the force of attraction but he did not unravel the understanding of gravitation, its nature or essence. However, knowing the Nature of gravitation is the key to understanding black holes which impose enormous gravitational forces, as we will see in the next pages.



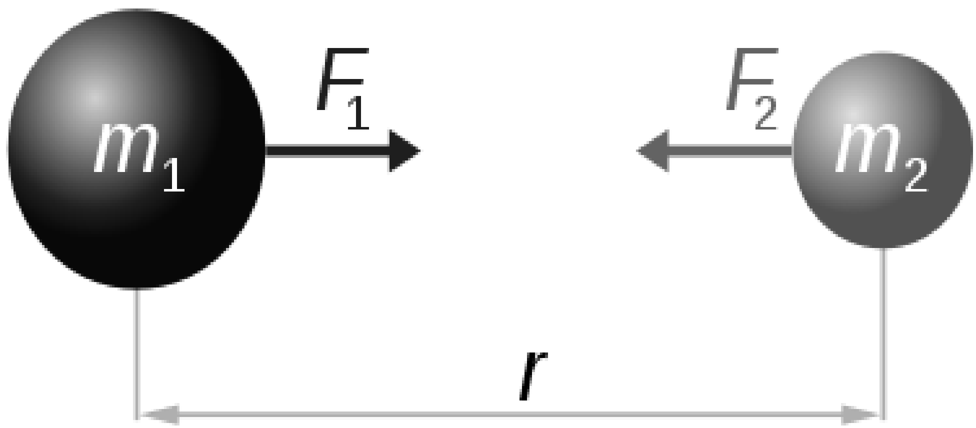
PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA

Autore J S. NEWTON, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

LONDINI,
Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

*Newton‘s great legacy, in Latin. A giant step forward in the understanding of the laws of nature, as early as 1686 (Wiki)*




$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$

*Newton´s formula for calculating the attraction between two masses, first published in the year 1686 (Wiki)*

Newton´s Law of Universal Gravitation is valid for all ‘point masses’ on Earth, in fact the entire Universe. It deals with two point masses named m1 and m2 in the distance r. The force between them is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. G is a constant. If we consider a black hole to be a point mass, the formula is valid for those as well.

Basically, this formula already reveals the problems which arise when the distance r is set at Zero, meaning that the celestial bodies have zero distance. By the law of mathematics, the result will become infinite. In mathematical calculations this is no problem. Mathematicians use this symbol for something which becomes infinitely large: $\infty$

How would we interpret it in physical terms? Can the force of attraction F become infinite, when two masses are aggregated to one point?

This would be a force stronger than anything known in The Universe. As a consequence of that, Newton´s formula can‘t be valid for very *small* distances.

*“Infinity? I cannot conceive. it“ (Photo: R.Brückner)*

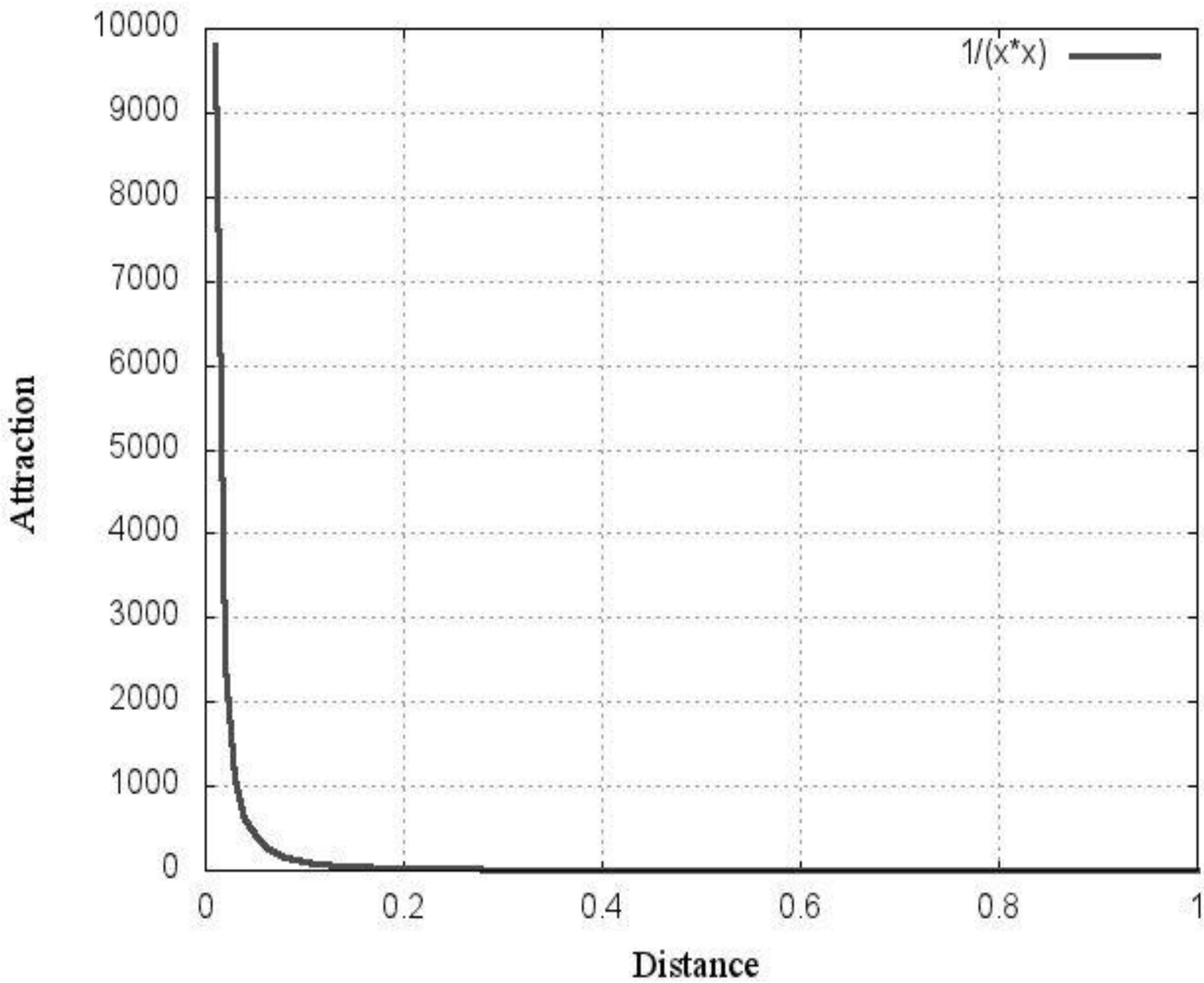
The human brain seems be incapable of comprehending the concept of ‘beyond infinity’ but *can* cope with finding solutions for real, earth-bound problems. For us, forces and distances on earth are easier to handle. Astronomical distances and forces overwhelm our thinking because we do not need them for Earthly survival.

Only 70 years after the death of Newton, **Henry Cavendish** calculated the constant G as a very low number. Cavendish was a British philosopher and scientist and is noted for his discovery of hydrogen which he called “inflammable air”. Much later it transpired that just the element hydrogen is essential for the building of stars and equally for black holes. So is the constant G.

$$G = 6{,}673\ 82 \times 10^{-11}\ \frac{m^3}{kg \times s^2}$$

This physical constant G is a natural constant determining how much two masses will attract each other. It is a distinct number. Were this number smaller, two masses would attract themselves to a lesser degree. e.g. The Sun & the Earth. As a consequence, the Earth would orbit at a greater distance from the Sun. Hence this could result in the Earth's receiving much less light and heat than is actually the case. It could possibly become too cold to sustain life.

Conversely, if the number G were greater, the Earth would orbit much more closely to the sun. The resulting greater temperature would render life quite impossible, water would evaporate and we might have the same conditions as exist today on the planet Venus. For that reason, it is crucial to all life that the physical constant G is as it is. This is not self-evident because G is related to space and time, and both are able to change as we will see in the next chapters. On the next page Newton´s formula is depicted in a diagram. The power of attraction F versus the distance r of the two masses m1 and m2 will be seen.




*Newton´s formula displaying the Force of Attraction F versus the Distance of 2 Masses (plotted with GnuPlot)*

In that diagram, it will be seen that when the distance r between two masses is reduced, the forces between them increases. In the case that the two masses concentrate at one point, the force F will become infinite. The computer program running “Gnuplot“ locked up when $F=10^4$ was exceeded.

If we assume one of the two masses to be a star and the other to be a black hole, there would be no way for the star to escape the black hole. The star would simply be dispatched and gulped by the Black Monster. Apparently a black hole is a lone wolf capable of massacring everything in its path.

# NEWTON'S THREE LAWS OF MOTION

*First law of motion: an object continues in its state of rest unless compelled to change that state by an external force*

*Second law of motion: if a force acts on an object, it will cause an acceleration*

*Third law of motion: for every action there is an equal and opposite reaction*

Is. Newton

*Trinity College in Cambridge, build 1350, later the domain of Isaac Newton (Wiki)*