SPONSORED BY

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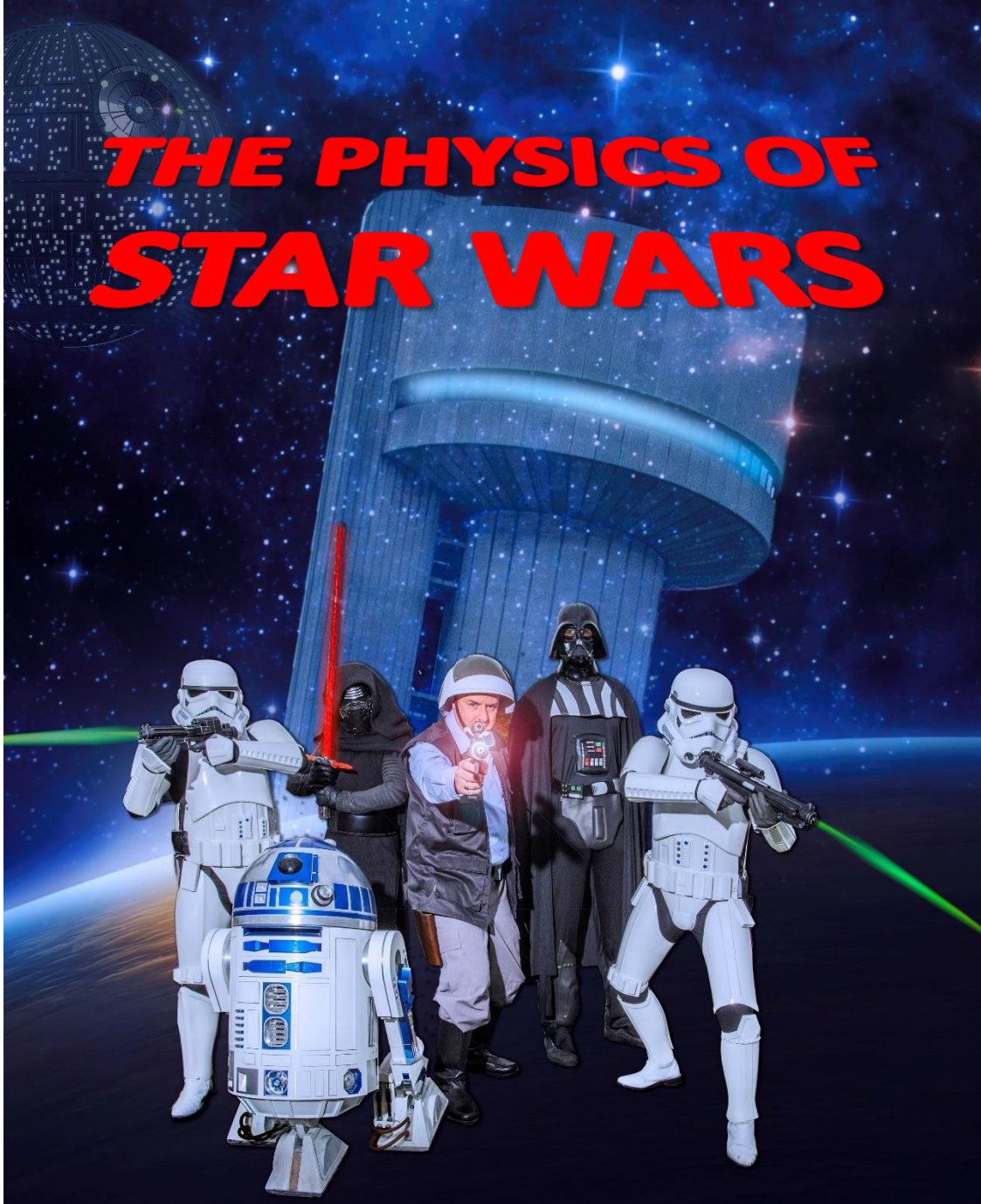
Produced by Dr Ricardo Torres, photographs by Alexandra Welsch.



What is science and what is fiction?

This is not an official Disney/Lucasfilm event, but planned, organised and run by Liverpool staff and students.

IN A GALAXY FAR FAR AWAY...

THE DARK SIDE

DEATH STAR

DROIDS

LIGHTSABER

HOTH

HYPERSPACE

MILLENNIUM FALCON

LIGHT SIDE VS. DARK SIDE

MILLENNIUM FALCON

Luke Skywalker and Han Solo set on a mission on board the Millennium Falcon to destroy the Empire's ultimate weapon– the Death Star. The Death Star was surrounded by a deflector shield that repelled the attacks. In order to succeed, the rebels had to deactivate the shield or penetrate it with their own super-weapon – the proton torpedo.

Fighting a cancerous tumour is like attacking the Death Star. The tumours are surrounded by healthy organs and tissues that must be spared for the good of the patient. Fortunately particle accelerators can produce real-life proton torpedoes to do just that.

CANCER-BUSTING PROTONS

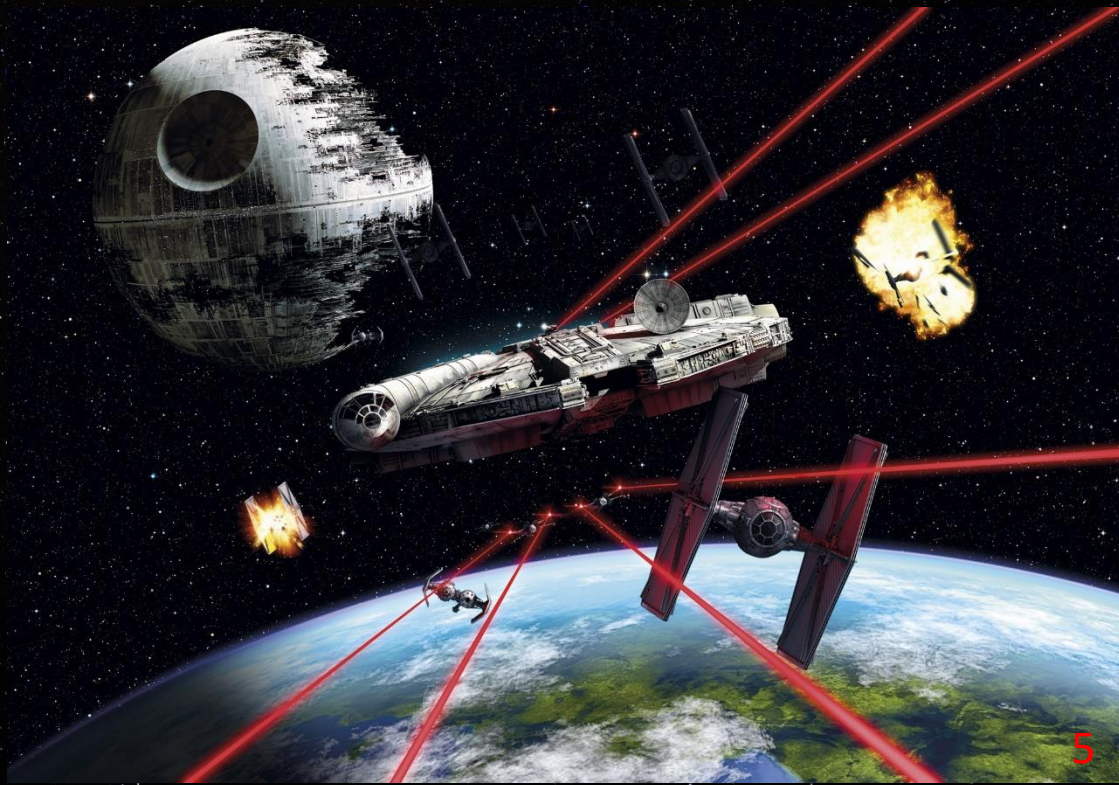
Just like proton torpedoes that can reach the innermost parts of the Death Star, protons can also be used for more precise and effective cancer treatment.

Proton beams are used to target cancer cells hidden deep inside the body of a patient. Protons are very effective at killing cancer cells because they release most of their energy when they stop, sparing the healthy tissue.

The QUASAR Group is conducting R&D in proton therapy, a novel radiotherapy technique that uses high-energy protons to treat cancer. Research is being done to direct protons with higher accuracy, to control the properties of the beam, and to monitor the entire process.

The University of Liverpool initiated the OMA project. The project carries out R&D into the optimisation of the underpinning accelerator technologies and advanced imaging systems to maximise the effectiveness of proton and ion beams for cancer treatment.

www.oma-project.eu



THE DARK SIDE OF THE FORCE

The dark side of the Force was an aspect of the Force, an energy field that connected everything in the Universe. Individuals who used the dark side drew their power from emotions such as fear, anger, and hatred. The Sith were the most well-known practitioners of the dark side, and were the mortal enemies of the Jedi Order, who served the light side of the Force.

The QUASAR Group is developing a gas jet-based monitor for the High Luminosity upgrade of the Large Hadron Collider at CERN. Any stray light from surrounding sources or synchrotron radiation would lower the quality of the measurement, therefore the monitor is enclosed in a cavity coated with Vantablack® - one of the darkest man-made substances.

HOW DARK CAN WE GO?

Some of the instruments that we use to measure the properties of particle beams are based on the detection of the light that they produce as they traverse a jet of gas. However, some particle accelerators emit a lot of light that can hinder the measurements. In order to make viable measurements the walls surrounding the instrument must absorb as much light as possible, i.e. they must be made of the darkest material.

DROIDS

The Star Wars Galaxy is full of fantastic droids, including R2-D2, C-3PO, BB-8, Rogue One's K-2SO, and the tiny little D-O.

Droids, short for androids, are mechanical beings, often possessing artificial intelligence. They are controlled by computers and are used in a variety of roles and environments, in fields that require extensive specialisation and knowledge.

We cannot match the level of sophistication of R2-D2 or BB-8, but we do use machine learning to optimise the control of particle accelerators and artificial intelligence for data analysis.

Data is generated continuously from multiple sources by companies, users and devices at a high speed, large volume and rich variety.

The LIV.DAT big data science centre for doctoral training at the University of Liverpool, is a hub for training students in managing, analysing and interpreting large, complex datasets and high rates of data flow.

www.livdat.org

DROIDS AND BIG DATA

Making the kind of intelligent droids featured in Star Wars requires a huge amount of data and the ability to analyse it.

Recent years have witnessed a dramatic increase of data in many fields of science and engineering, due to the advancement of sensors, mobile devices, biotechnology, digital communication, and internet applications.

HOTH

Hoth was a remote, icy planet that hosted the temporary headquarters of the Rebel Alliance until the Galactic Empire located them, initiating a major confrontation known as the Battle of Hoth. The surface of Hoth was covered with glaciers and frozen ice plains. The temperature, was known to drop to -60°C at night.

Although -60°C sounds cold, it's HOT compared with the temperatures needed to run a particle accelerator. The superconducting materials used in some accelerating cavities and bending magnets only become superconducting at extremely low temperatures. Cryogenics is also used in particle detectors to keep heavy gases such as argon or krypton in a liquid state.

In the QUASAR Group, we use superconductors in ultra-sensitive monitors as they can be used to measure the smallest magnetic fields. We have developed a new type of monitor for low energy antimatter beams, where nano-amp beams can be measured non-invasively.

HOW *COOL* IS THAT?

In the Large Hadron Collider the superconducting magnets are kept in a bath of liquid helium at -271 °C, colder than outer space. Liquid nitrogen is relatively warm in comparison (-196 °C), but it can still freeze you to death in under two seconds!

DEATH STAR

The Death Star was a moon-sized battle station constructed by the Galactic Empire. Its purpose was to terrorise planets and star systems in league with the Rebel Alliance through the use of its planet-destroying super-laser.

After the destruction of the first Death Star by the Alliance, the Empire established a shield generator complex on Endor to protect the construction of the Death Star II from Rebel assaults.

Deflector shields were energy fields made of rays or particles that bend around starships and battle stations to protect them from enemy attacks.

BENDING THE BEAM!

In particle accelerators we use magnets and electrostatic fields to bend beams of particles.

Magnets can exert a force on electric currents and vice-versa. A beam of charged particles is nothing but an electric current travelling in a vacuum so it is subject to the same principles. The force exerted by a magnetic field on a charged particle is called the Lorentz force.

Members of the QUASAR Group work on the simulation of electromagnetic fields deflecting particle beams in order to optimise the performance of particle accelerators.


Van De Graaff Generator

HYPERSPACE

Intergalactic starships can get to the other side of the galaxy in a matter of seconds by travelling through the hyperspace. In order to reach hypervelocity every aspiring pilot has to master the techniques of surfing on the ripples of spacetime.

A new type of particle accelerators uses the waves produced in the wake of a proton beam travelling through a plasma to accelerate electrons to very high energies in a very short distance. This technique is called 'wakefield acceleration'.

SURFING THE WAVE!

Electrons in a wakefield are accelerated by riding the plasma waves, just like a surfer at sea. In the former, the force acting upon the electrons is the electric field that arises between the waves, whereas the force that accelerates the surfer is gravity.

The amplitude, wavelength and frequency of the plasma waves can be controlled by varying the energy of the proton beam and the density of the plasma.

The electron beam must be injected into the plasma at the right time and with the right speed in order to catch the plasma wave and obtain a maximum acceleration.

As part of the AWAKE collaboration, the QUASAR Group is developing novel beam monitors that help finding the optimum conditions to accelerate the electrons, as well as the means to synchronise the electron beam to the plasma waves to maximise the energy gain.

www.awake-uk.org


Surfatron

LIGHTSABER

The lightsaber was the signature weapon of the Jedi Order and their Sith counterparts.

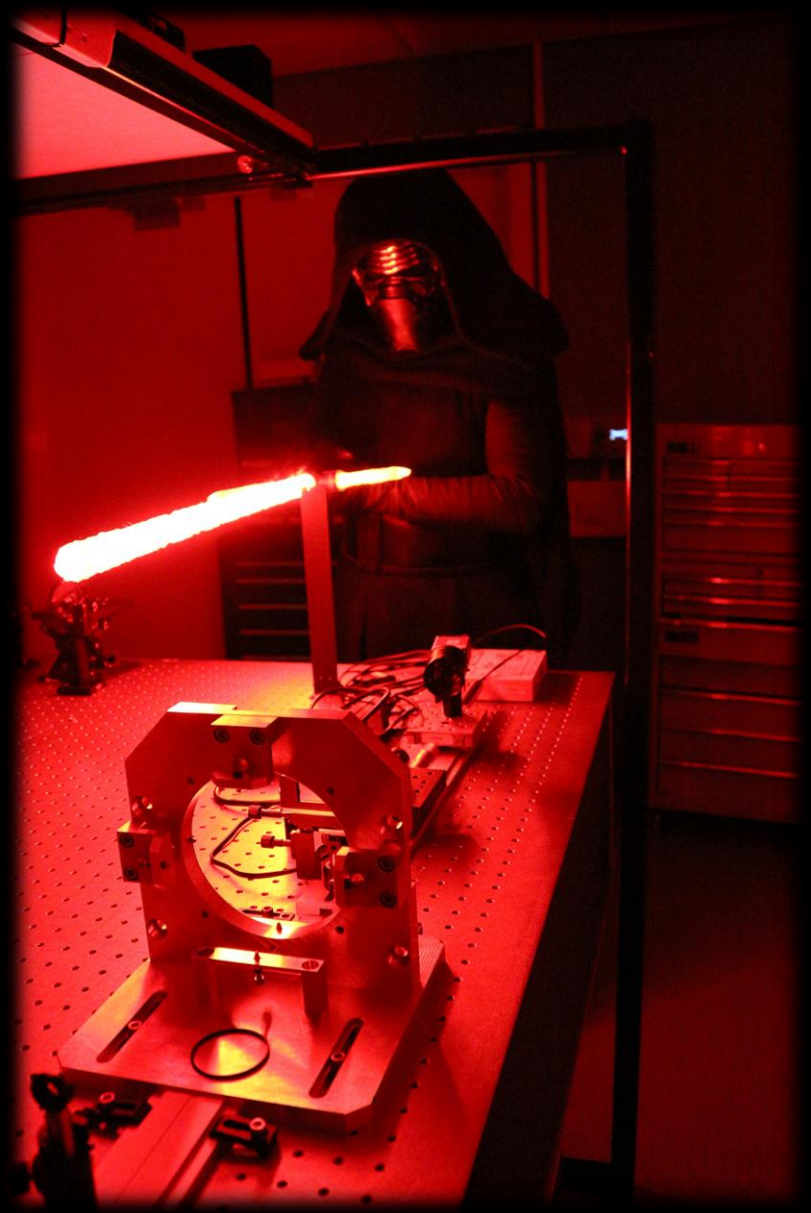
This powerful energy sword consisted of a blade of pure plasma which could cut, burn, and melt through most substances with little resistance.

LASERS AND ACCELERATORS

Like the iconic lightsaber, weapon of choice for those strong with the Force, there are already many exciting laser applications, such as laser knives controlled by robot arms for high-precision surgery and adaptive manufacturing using lasers for creating complex metallic structures.

The QUASAR Group is part of the international EuPRAXIA design study. Accelerator scientists in this study are using lasers to design a new type of accelerator that uses plasma wakefields, promising gradients as high as some tens of billions volts per meter.

www.eupraxia-project.eu



LIGHT SIDE VS. DARK SIDE

The light side against the dark side, the eternal battle between good and evil, the imbalance in the Force, is portrayed in the Star Wars saga.

Just like this imbalance between the light and the dark side, scientists are trying to solve the mystery of the imbalance between matter and antimatter.

A DISTURBANCE IN THE FORCE

The Physics' standard model says that the Big Bang should have created matter and antimatter in equal amounts, but hardly any antimatter is seen in the observable universe. Where did all the antimatter go?

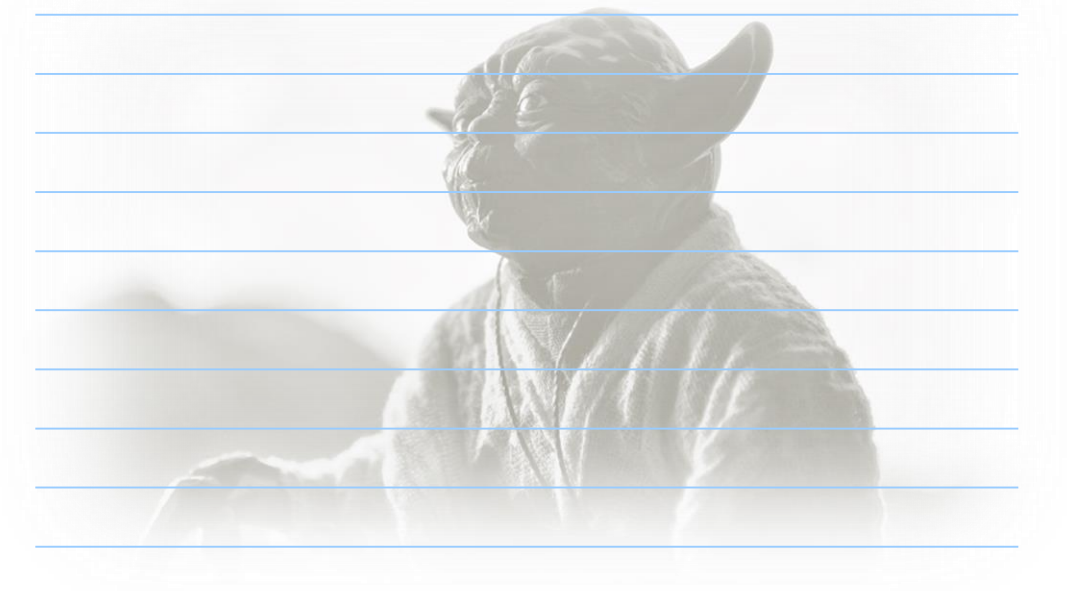
The University of Liverpool is involved in antimatter research through AVA. The project is carrying out research across facility design and optimisation, advanced beam diagnostics and novel low energy antimatter experiments to unravel one of the great unsolved problems in physics.

www.ava-project.eu

MUCH TO LEARN ...

...YOU STILL HAVE ...

… MY YOUNG PADAWAN



The University of Liverpool's Quasar Group

The QUASAR Group is an internationally structured research group with members based at the Cockcroft Institute, Daresbury Laboratory, in Liverpool, as well as at CERN and other partner organisations around the world. It was founded and is led by Professor Carsten P Welsch. We cover the development and experimental exploitation of particle accelerators and light sources.

Our present research activities include:

- **Frontier Accelerators**, such as the Large Hadron Collider at CERN and its upgrade programs;
- **Novel Accelerators**, including dielectric laser accelerators and particle-driven plasma wakefield accelerators;
- **Accelerator applications** with a focus on medical applications, laser applications and compact radiation sources;
- **Beam instrumentation** R&D;
- **Beam dynamics** studies to optimize accelerators and light sources.

The QUASAR Group coordinates the EU Projects OMA and AVA, and it is a partner in the EuroCirCol, EuPRAXIA and AWAKE projects.

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MAY THE FORCE BE WITH YOU