DARK MATTER.

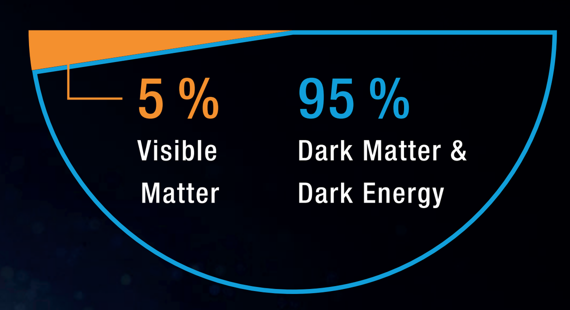
Hunting for new particles

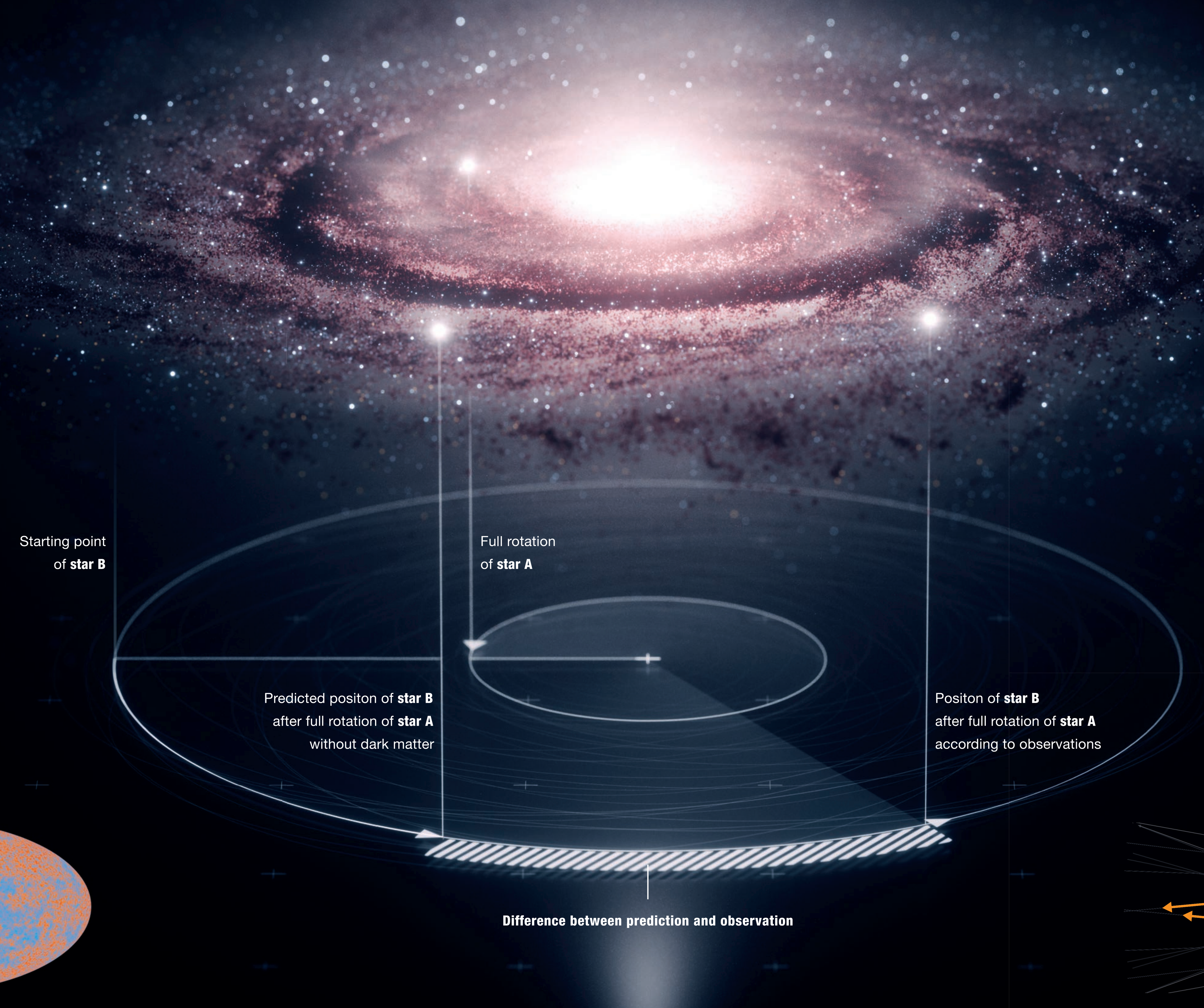
Physicists have been searching for the mysterious dark matter for many decades. As early as the 1930s, astronomers had been puzzled by a strange finding: galaxies held together even though they should actually fly apart. In addition to the visible celestial objects – stars, planets and clouds of gas and dust – there must therefore be some kind of invisible matter whose gravity keeps the galaxies in check. But what is this ominous dark matter, without which it's almost impossible to explain how galaxies and galaxy clusters formed as the universe developed? Could it consist of still undetected, ultralight or extremely heavy elementary particles? And are black holes related to this phenomenon? Around the world, the search is on, and a new generation of experiments might soon be able to finally solve the mystery of dark matter.

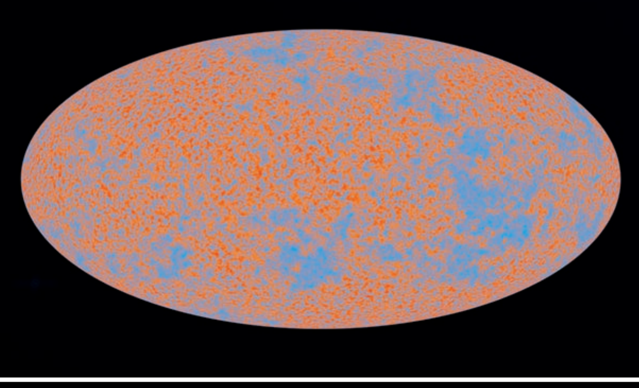
Evidence for the existence of dark matter

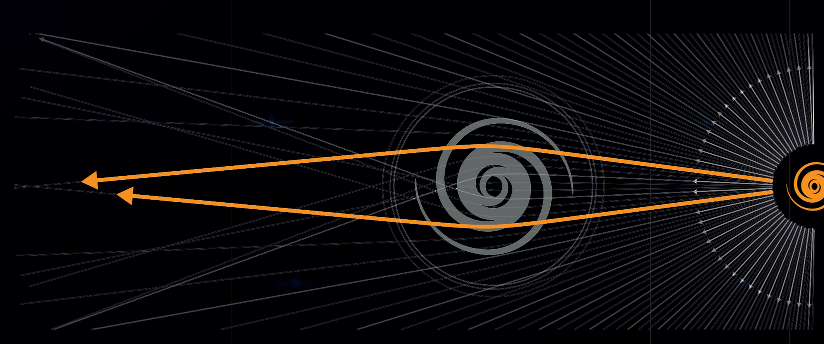
The strangest substance in the universe: dark matter is more than five times more abundant in the cosmos than the matter we are familiar with. It does not interact with electromagnetic radiation such as light and is thus completely invisible.

Composition of the universe









Temperature fluctuations

The cosmic microwave background radiation arose 380,000 years after the Big Bang and is still billowing through the Universe. Small temperature fluctuations such as those measured by the European satellite "Planck" served as the seeds of future structures such as galaxy clusters. The distribution of these tiny fluctuations indicate that dark matter already existed before any galaxies formed.

Rotation speed

In the 1970s, scientists found out that stars orbiting the centre of a galaxy are moving so rapidly that they should actually be catapulted out. Their conclusion was that in addition to the visible celestial objects – stars, planets and clouds of gas and dust – there must also be some kind of invisible or "dark" matter. The gravity of this matter keeps the stars in a galaxy in check and has prevented our Milky Way, for example, from drifting apart long ago.

Gravitational lensing

Other evidence for the existence of dark matter is an effect called gravitational lensing. Light from distant galaxies is deflected slightly because of dark matter's gravitational pull.

Dark matter candidates

	Hypothetical elementary particles						Other canidates
Group / Particle	**WISP** Axion	**Neutrinos** Sterile Neutrino	**FIMP** -	**WIMP** Neutralino	**SIMP** -	**SuperWIMP** Gravitino	**MACHO** Primordial black hole
Description	Weakly Interacting Slim Particle	Warm Dark Matter	Feebly Interacting Massive Particle	Weakly Interacting Massive Particle	Strongly Interacting Massive Particle	Supersymmetric Particle	Massive Compact Halo Objects
Mass	up to 1 meV	in the keV range	MeV to GeV	about 100 GeV	in the GeV range	GeV to TeV range	extremly massive
Interaction strength	extremely weak	medium	extremely weak	medium	strong (dark sector)	extremely weak	gravitational, very weak
Searchmethod	● ○ ■	● ○ ■	● ○ ■	● ○ ■	● ○ ■	● ○ ■	● ○ ■

Legend

Interaction strength — Mass

Mass
µeV meV eV keV MeV GeV TeV

Interaction strength
weak medium strong

Type of search
● Direct detection ○ Indirect detection ■ Creation

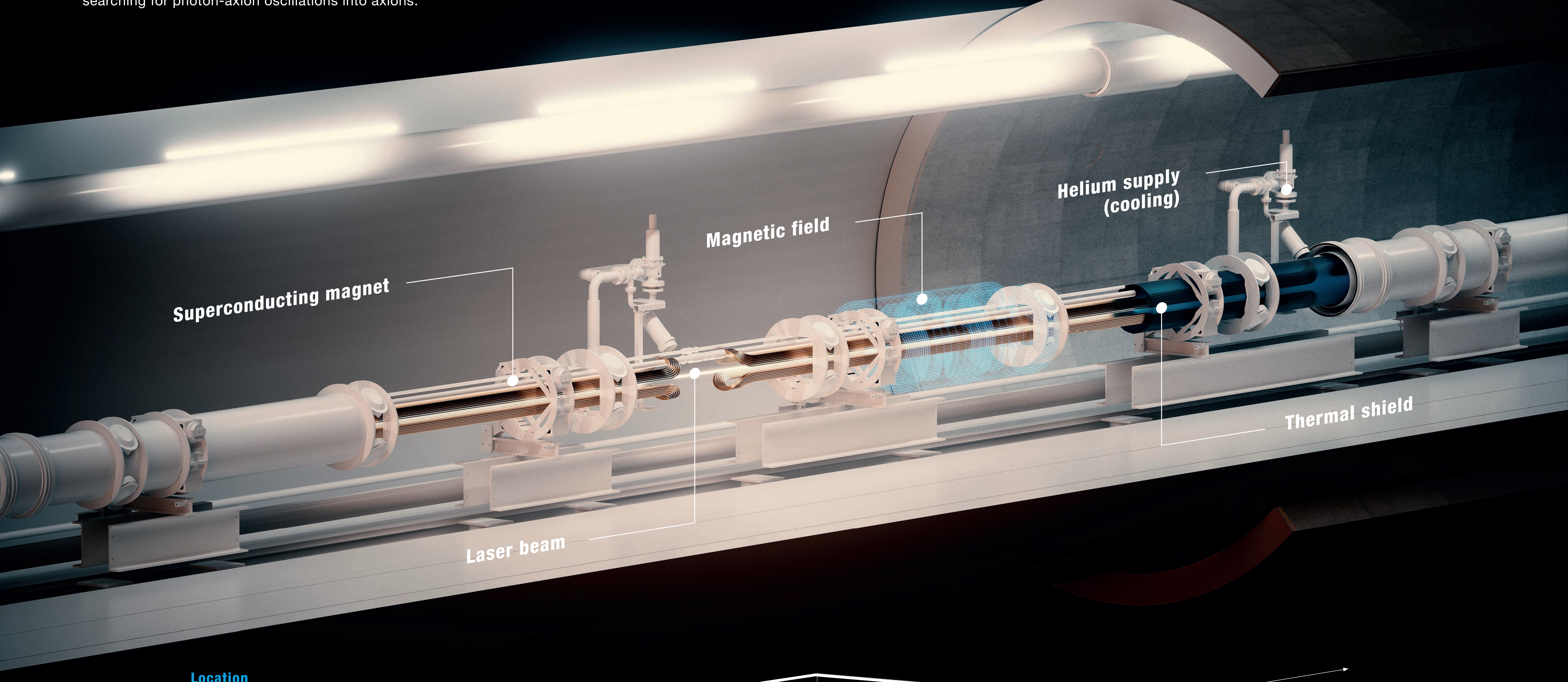
Experiments

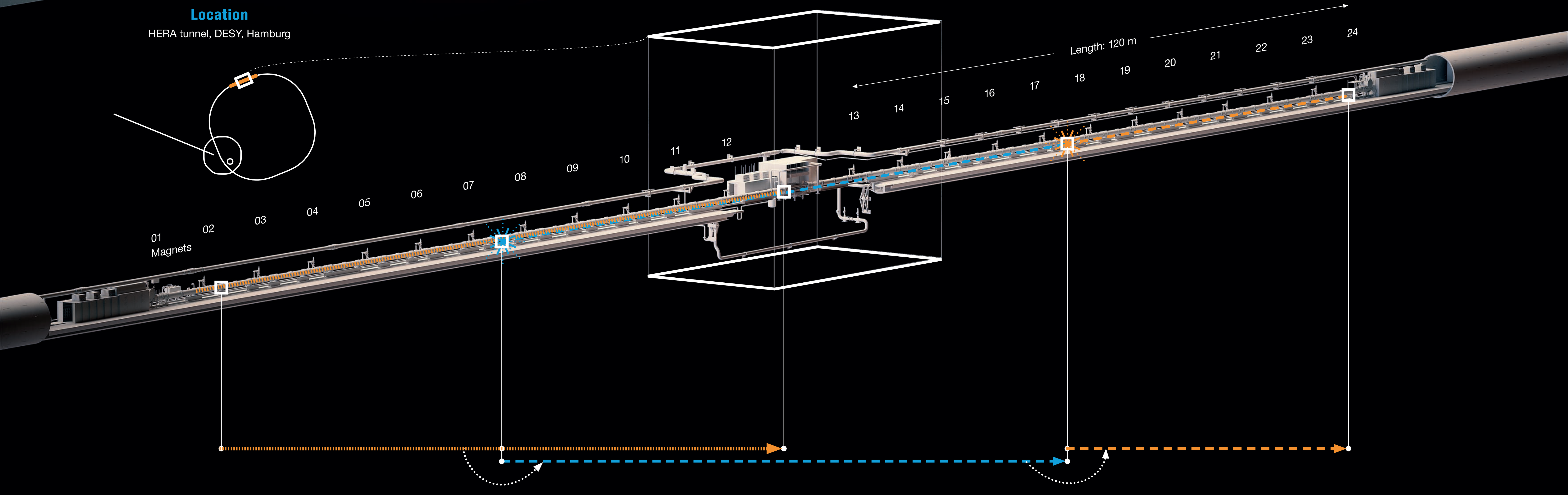
Category	Particle detector	Space-based telescopes	Ground-based telescopes	Particle detectors at accelerators	Non-accelerator lab experiments
Experiments (selection)	ADMX, FUNK, LUX, LUX-Zeplin, MADMAX, XENONnT	AMS, Chandra, FGST-GBM, FGST-LAT, NuSTAR, PAMELA, XRISM	CAST, CTA, H.E.S.S., IAXO, IceCube, MAGIC	ATLAS, Belle-II, CMS, HPS, LHCb	ALPS II, ARIADNE, PVLAS, KATRIN/TRISTAN, Troitsk nu-mass
Type of search	● Direct detection	○ Indirect detection	○ Indirect detection	■ Creation	■ Creation

ALPS II.

Making light go through walls

ALPS II is a “light shining through a wall“ experiment searching for photon-axion oscillations into axions.





1 **Laser beam**

Light from a laser gets amplified in an optical cavity – basically a huge mirror chamber.

2 **Transformation of photon into axion**

The light passes through a strong magnetic field from twelve superconducting magnets. According to theory, this is where a photon transforms into an axion with the probability of: $1{:}10^{14}$

3 **Wall**

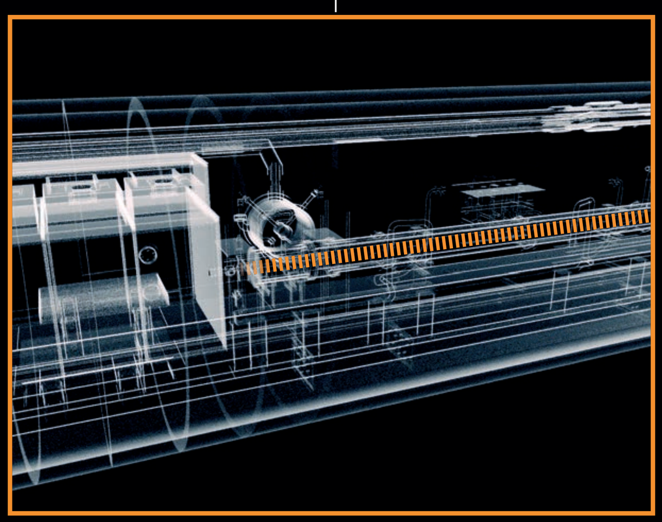
Laser light is stopped by the wall. The axion would simply pass through the wall.

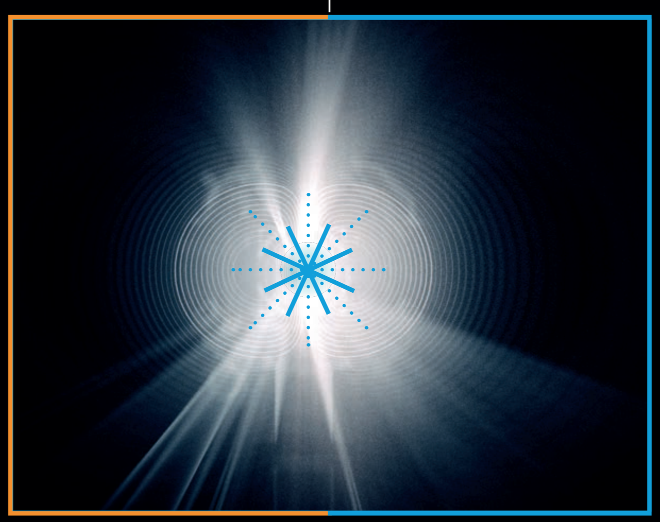
4 **Transformation of axion into photon**

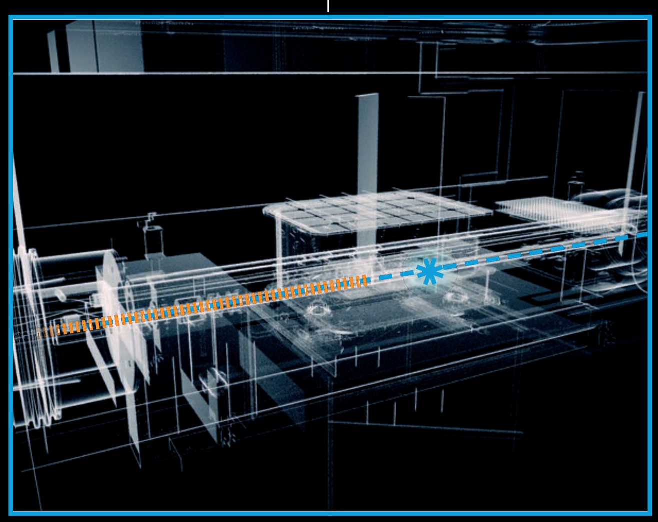
In the magnetic field on the other side, the axion is transformed back into a photon.

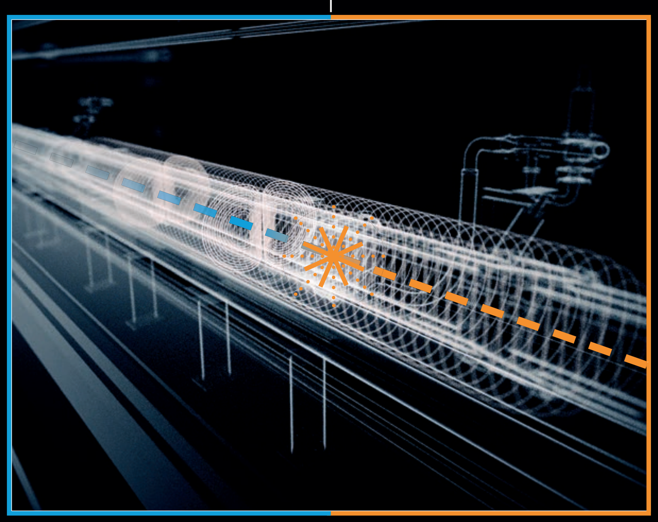
5 **Detector**

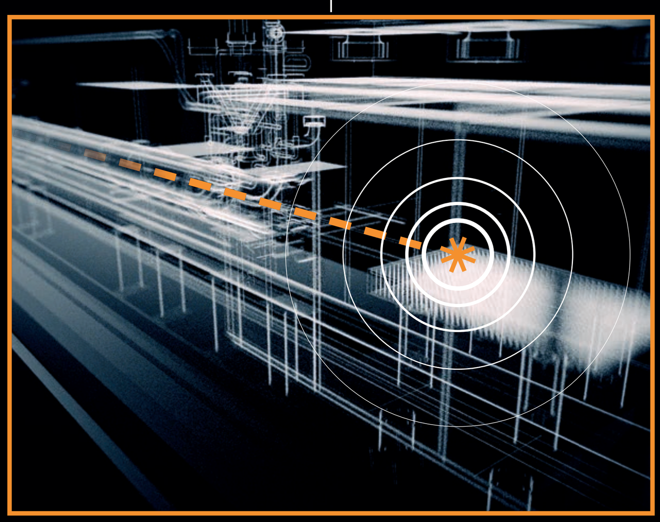
These transformations are extremly rare. That is why the detector must also be extremely sensitive. It must be able to detect a few photons per day.











ALPS II main contributions

	DESY	Leibniz Universität Hannover / Max Planck Institute for Gravitational Physics (Albert Einstein Institute)	Cardiff University	University of Florida	Johannes Gutenberg Universität Mainz
Magnets	●				
Optics	●	●	●	●	
Detectors	●			●	●
Infrastructure	●			●	

Imprint

Publisher: DESY
Design: Science Communication Lab