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Observing the gravitational universe from space

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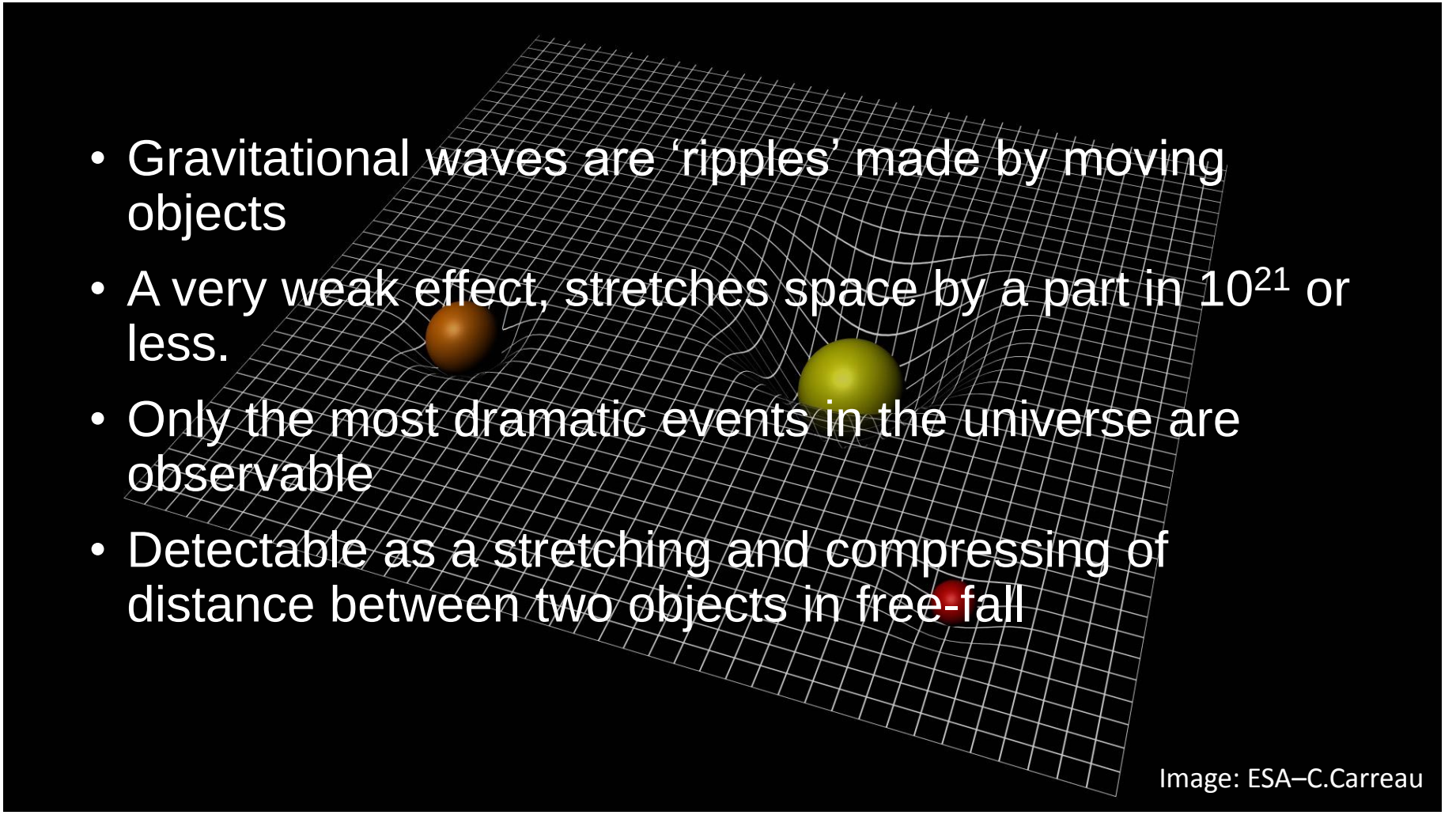
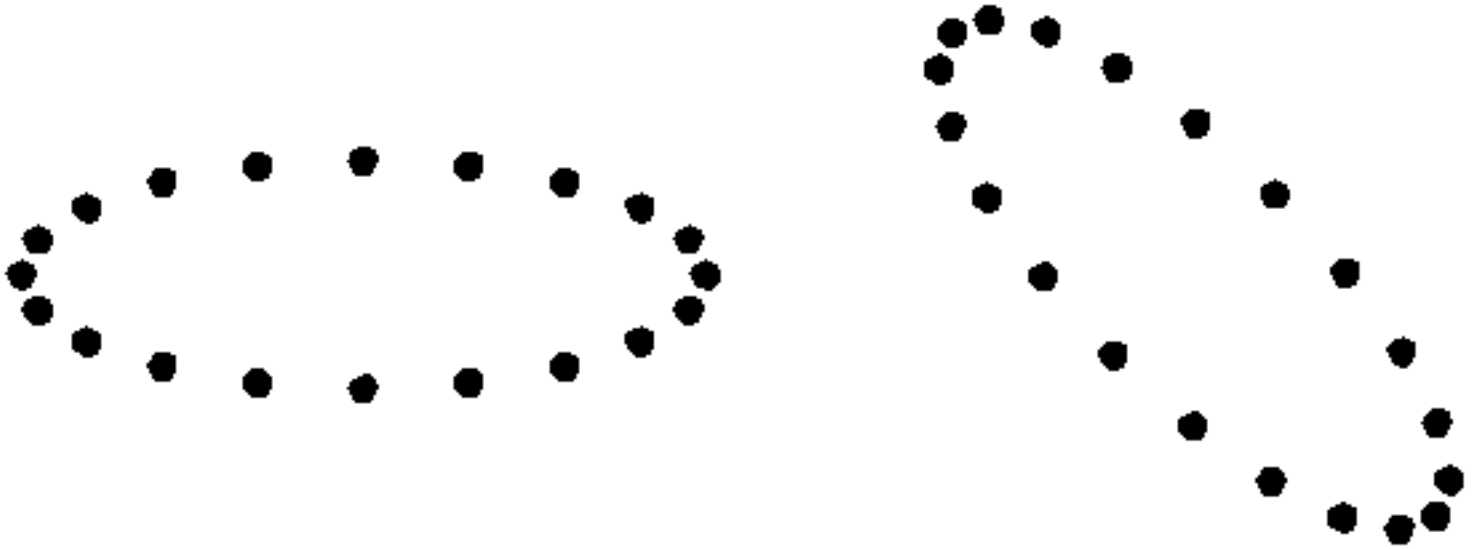
Gravitational Waves



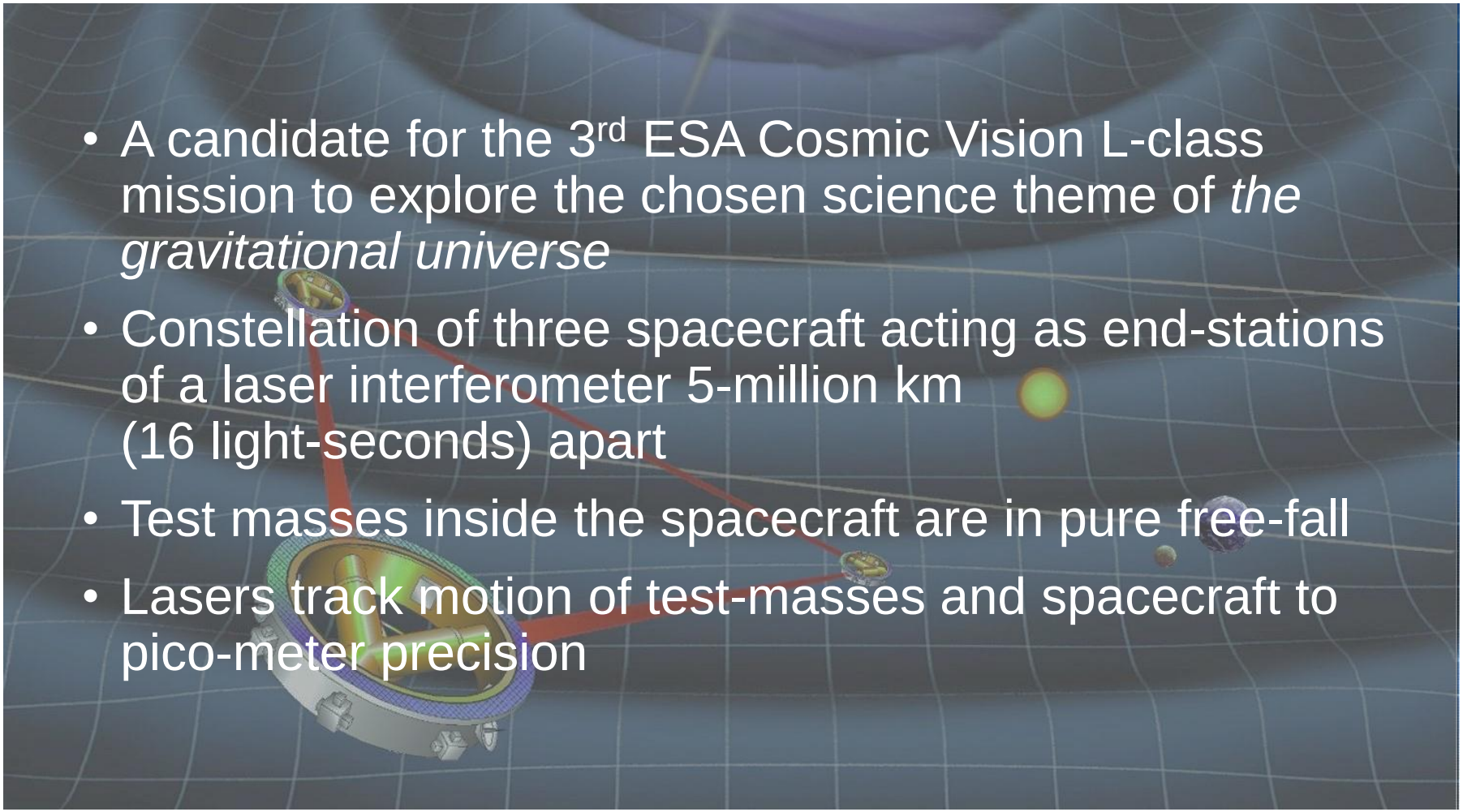
- Gravitational waves are ‘ripples’ made by moving objects
- A very weak effect, stretches space by a part in 10^{21} or less.
- Only the most dramatic events in the universe are observable
- Detectable as a stretching and compressing of distance between two objects in free-fall

Image: ESA–C.Carreau

Gravitational Waves



LISA



- A candidate for the 3rd ESA Cosmic Vision L-class mission to explore the chosen science theme of *the gravitational universe*
- Constellation of three spacecraft acting as end-stations of a laser interferometer 5-million km (16 light-seconds) apart
- Test masses inside the spacecraft are in pure free-fall
- Lasers track motion of test-masses and spacecraft to pico-meter precision

LISA

- A gravitational wave antenna scanning the sky over the course of a 1-year orbit
- Will detect thousands of sources simultaneously that need to be carefully extracted from the noise

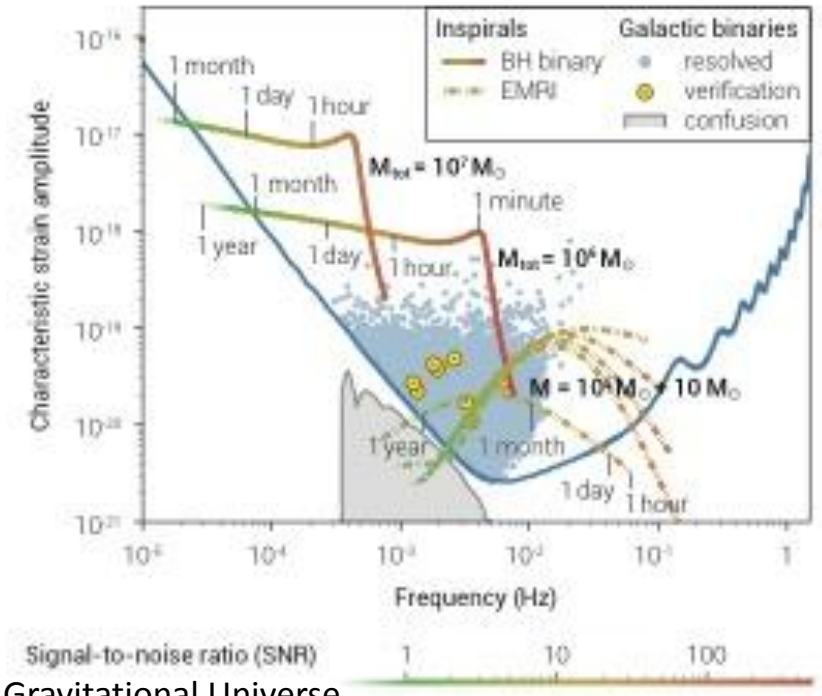


Image: Gravitational Universe

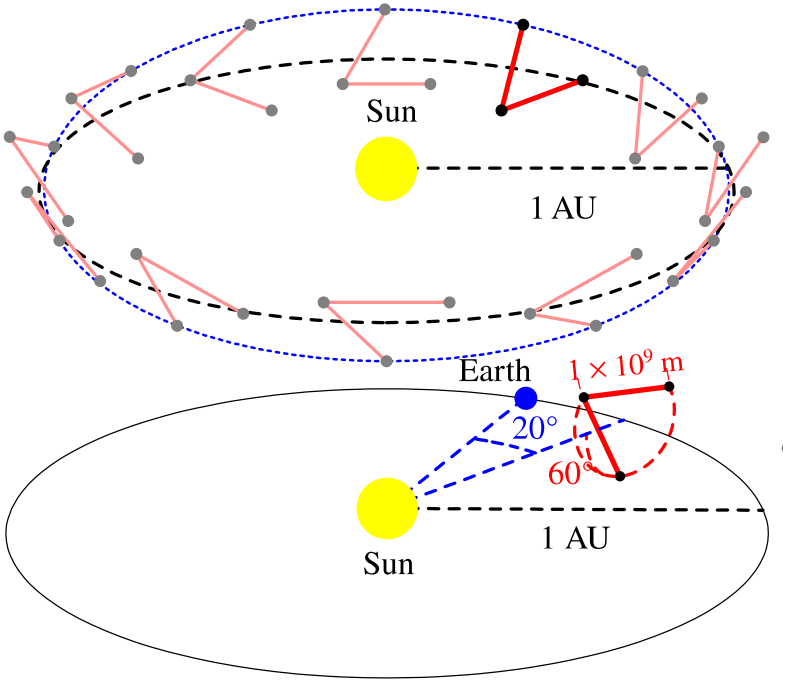


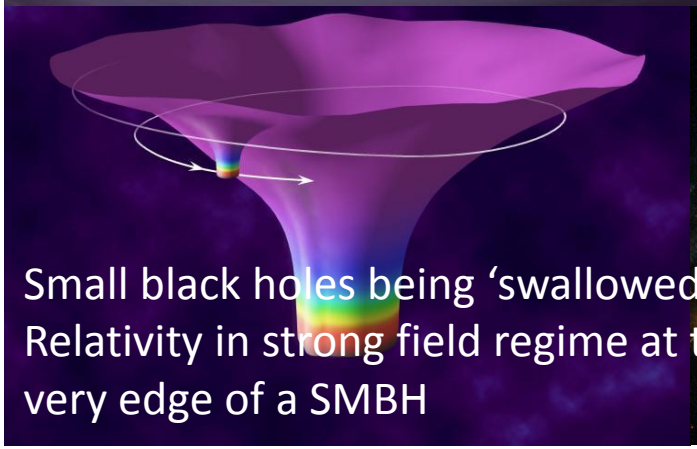
Image: NGO-YB

LISA

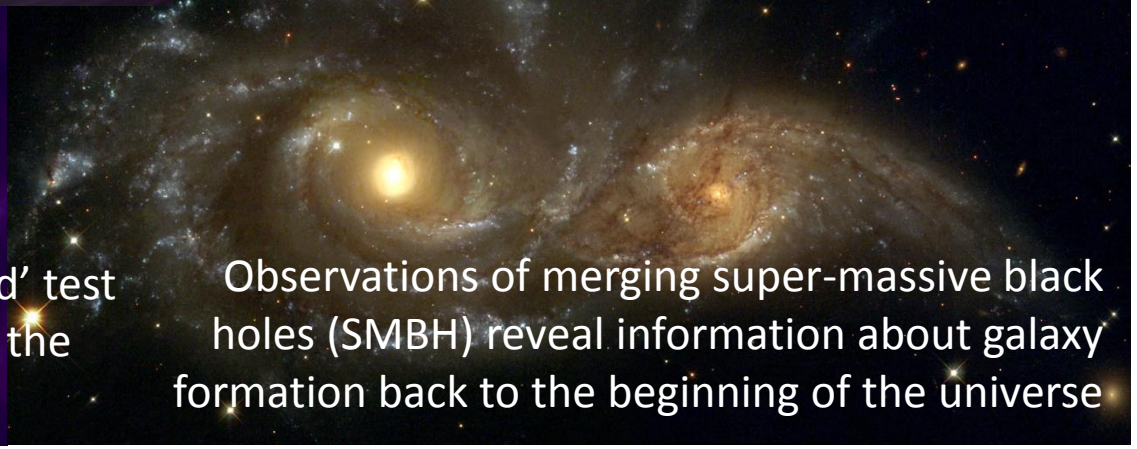
In our galaxy LISA will observe thousands of compact binary systems

Many systems that we know ‘should’ be emitting GWs

Something completely new?



Small black holes being ‘swallowed’ test Relativity in strong field regime at the very edge of a SMBH



Observations of merging super-massive black holes (SMBH) reveal information about galaxy formation back to the beginning of the universe

LISA Pathfinder

- LISA is a completely new kind of space mission
- ESA decided on a dedicated proof-of-concept mission to reduce risk
- First proposed in 1998 now ready for launch in November

lisa pathfinder

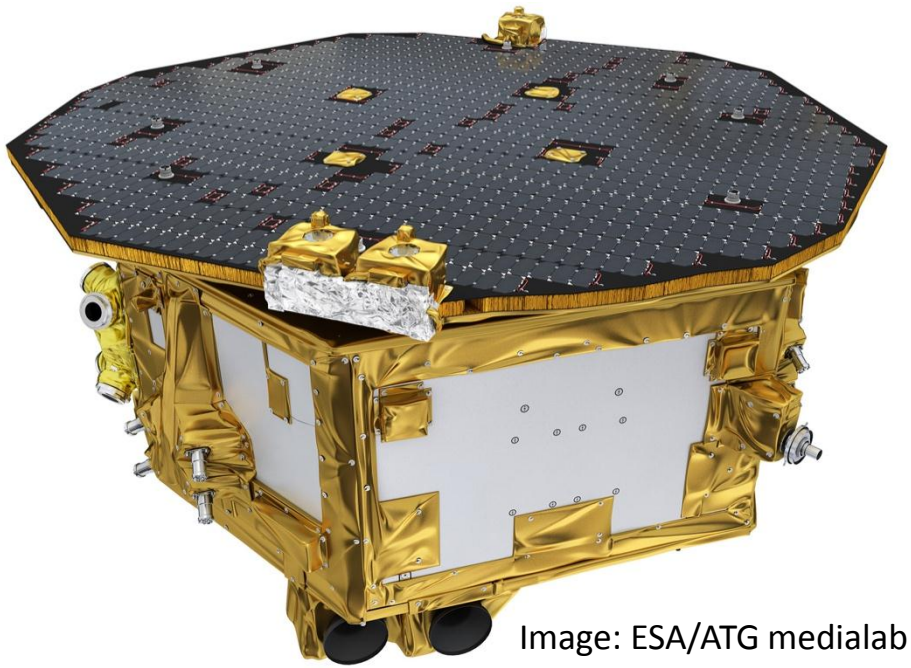


Image: ESA/ATG medialab

LISA Pathfinder

UK Contributions

Airbus Defence and Space
Spacecraft prime contractor

ABSL
Battery

Scisys
On-board SW

Imperial College London
Charge management

University of Glasgow
Optical bench

University of Birmingham
Phasemeter

MSSL
Photodiodes

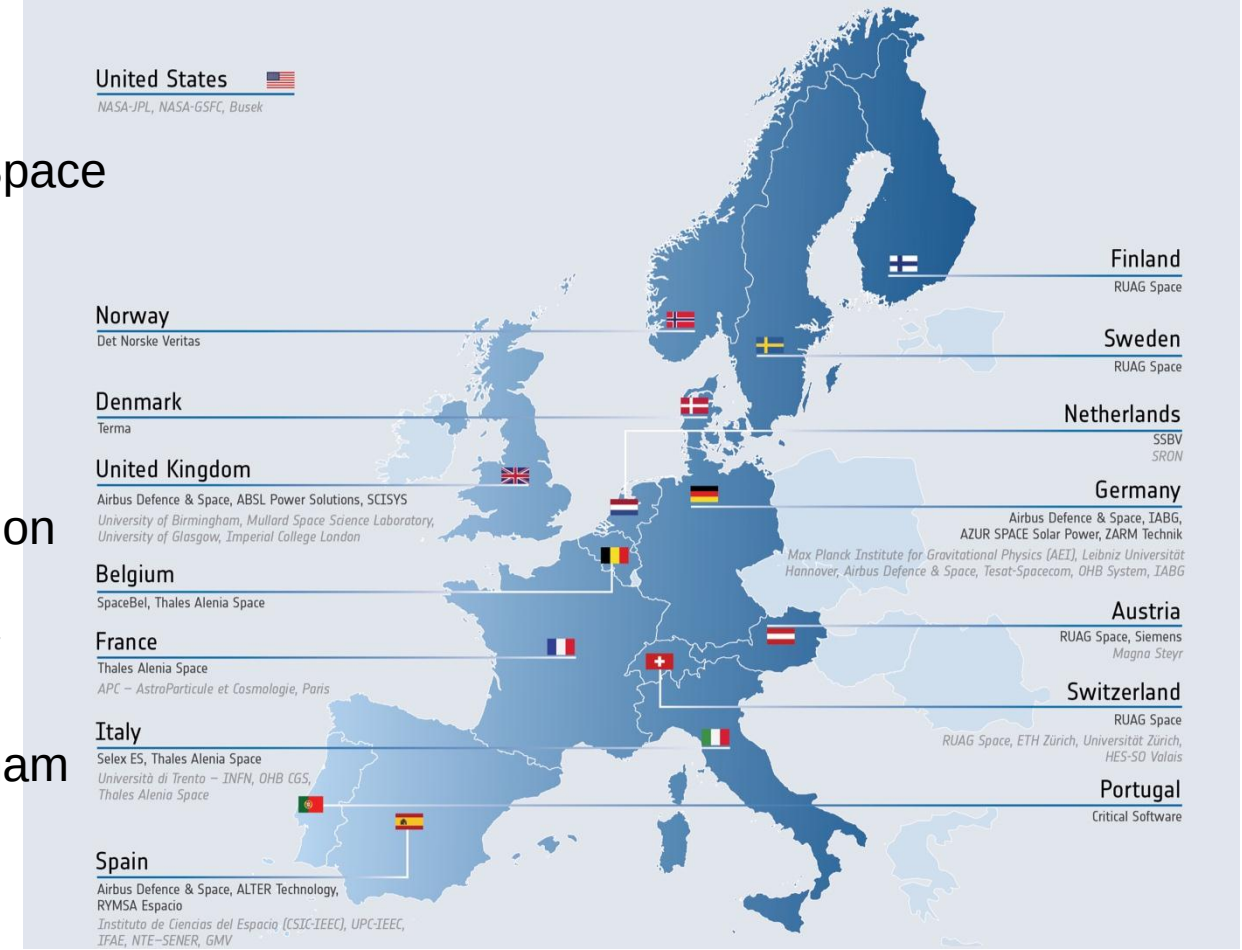


Image: ESA/ATG medialab

LISA Pathfinder

- Two test masses separated by 38cm inside one spacecraft - no gravitational wave detection
- Capacitive inertial sensors detect test mass position
- Micro-Newton thrusters allow the spacecraft to follow the test mass motion

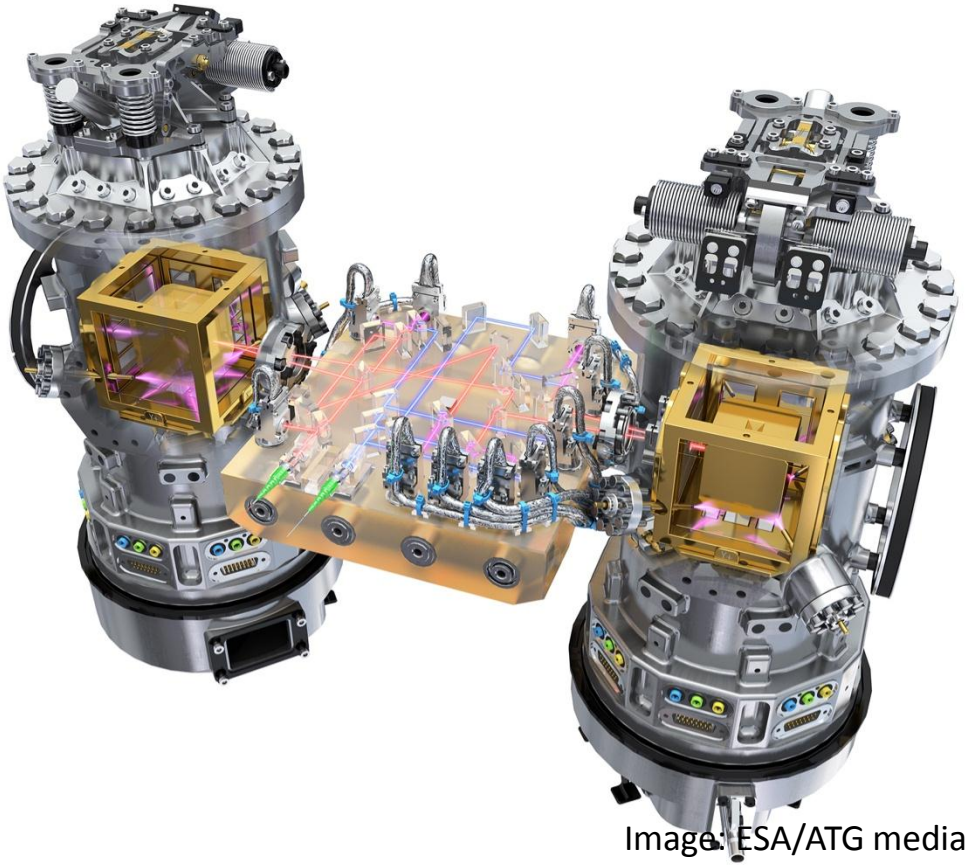


Image: ESA/ATG medialab

LISA Pathfinder

- Laser interferometer measures relative motion of masses to 10pm precision
- Measure forces that could limit GW detection: below 60fN/√Hz in the measurement band

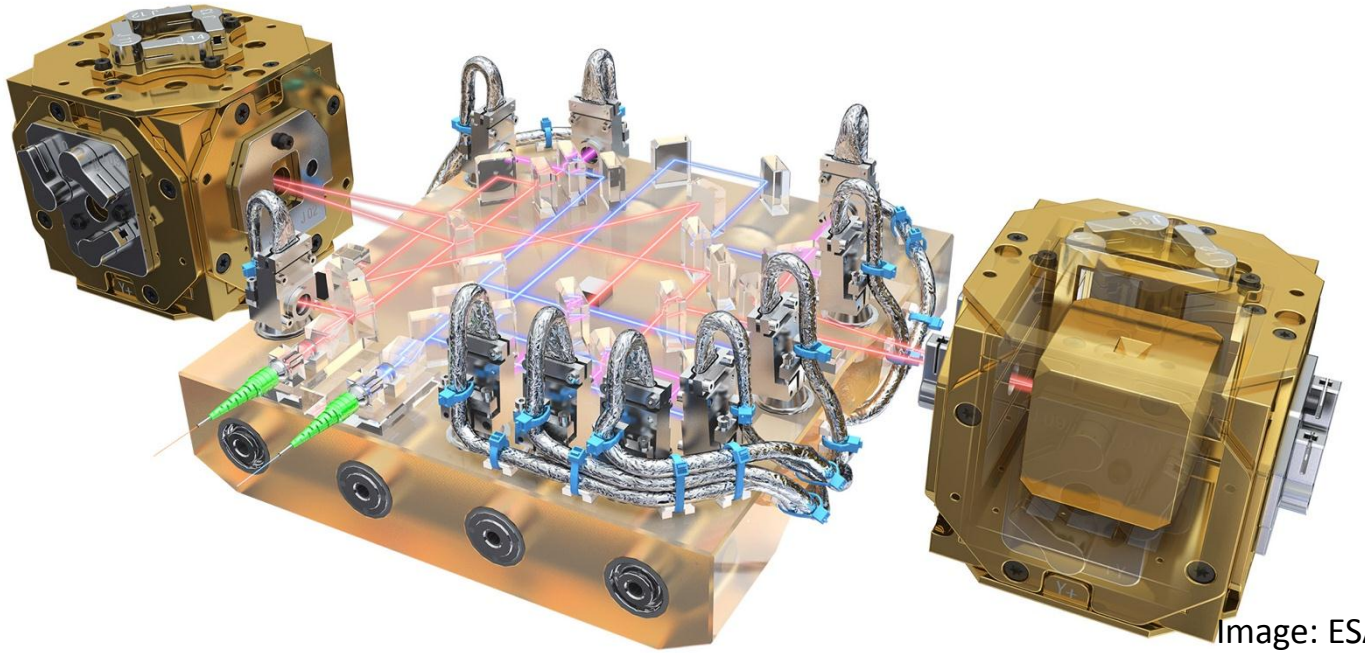


Image: ESA/ATG medialab

Test mass charging

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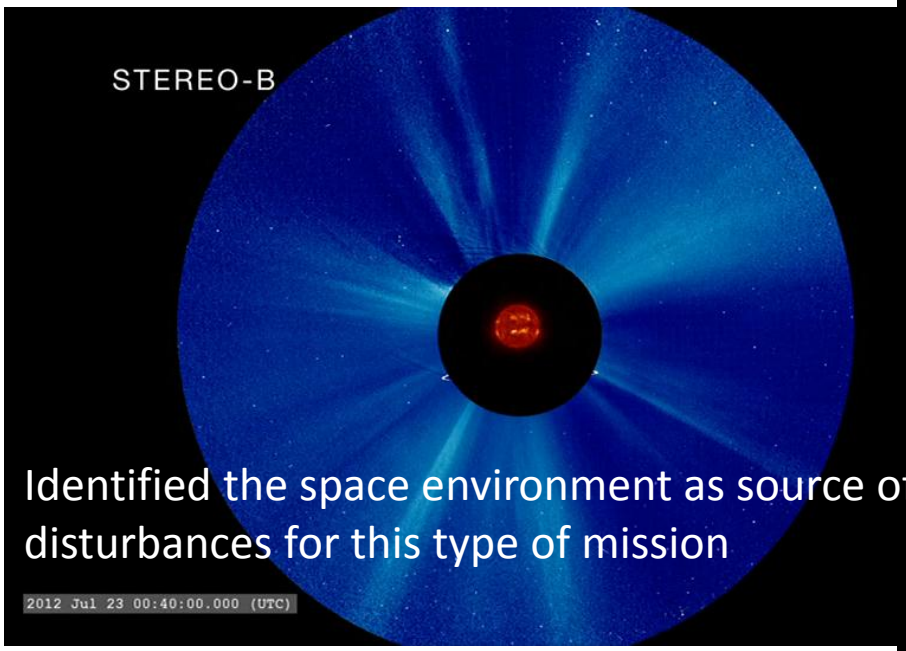
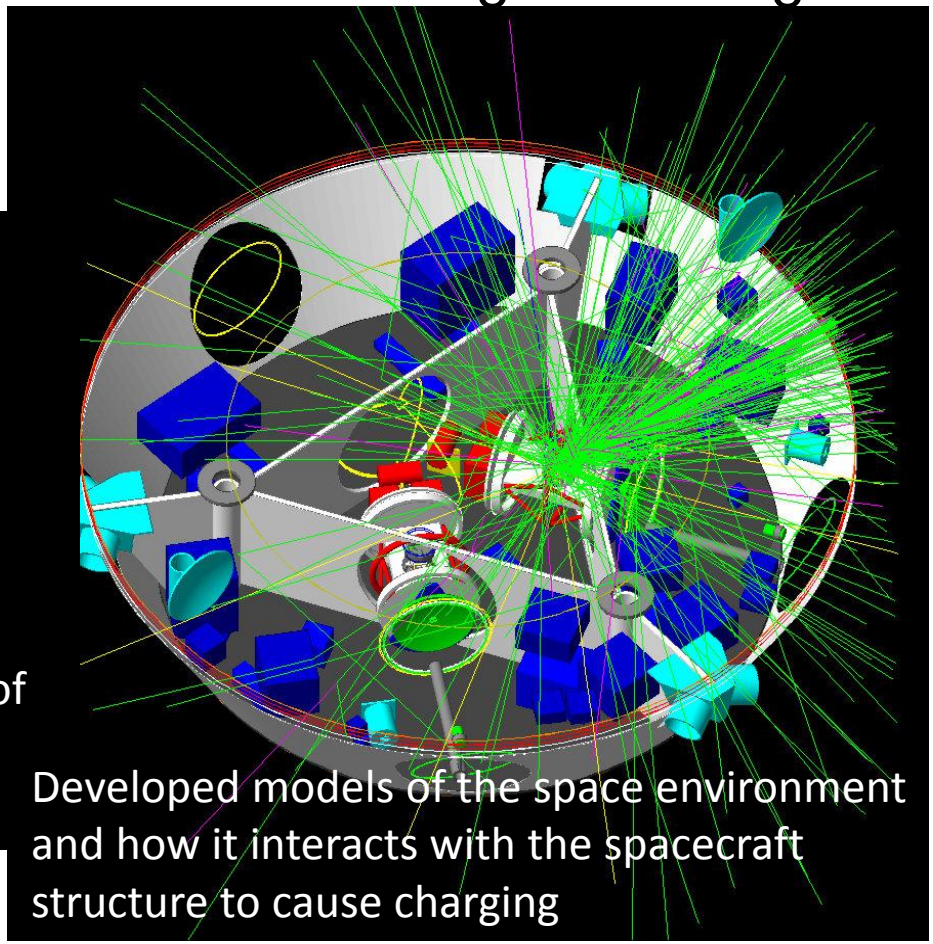
Free-falling test masses will accumulate charge resulting in electrostatic forces



Identified the space environment as source of disturbances for this type of mission



Developed models of the space environment and how it interacts with the spacecraft structure to cause charging

Image: NASA/STEREO

Test mass charging

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- Neutralise the test mass with non-contact method
- Illuminate gold surfaces with ultra violet light
- Transfer charge to or from the test mass by photoemission

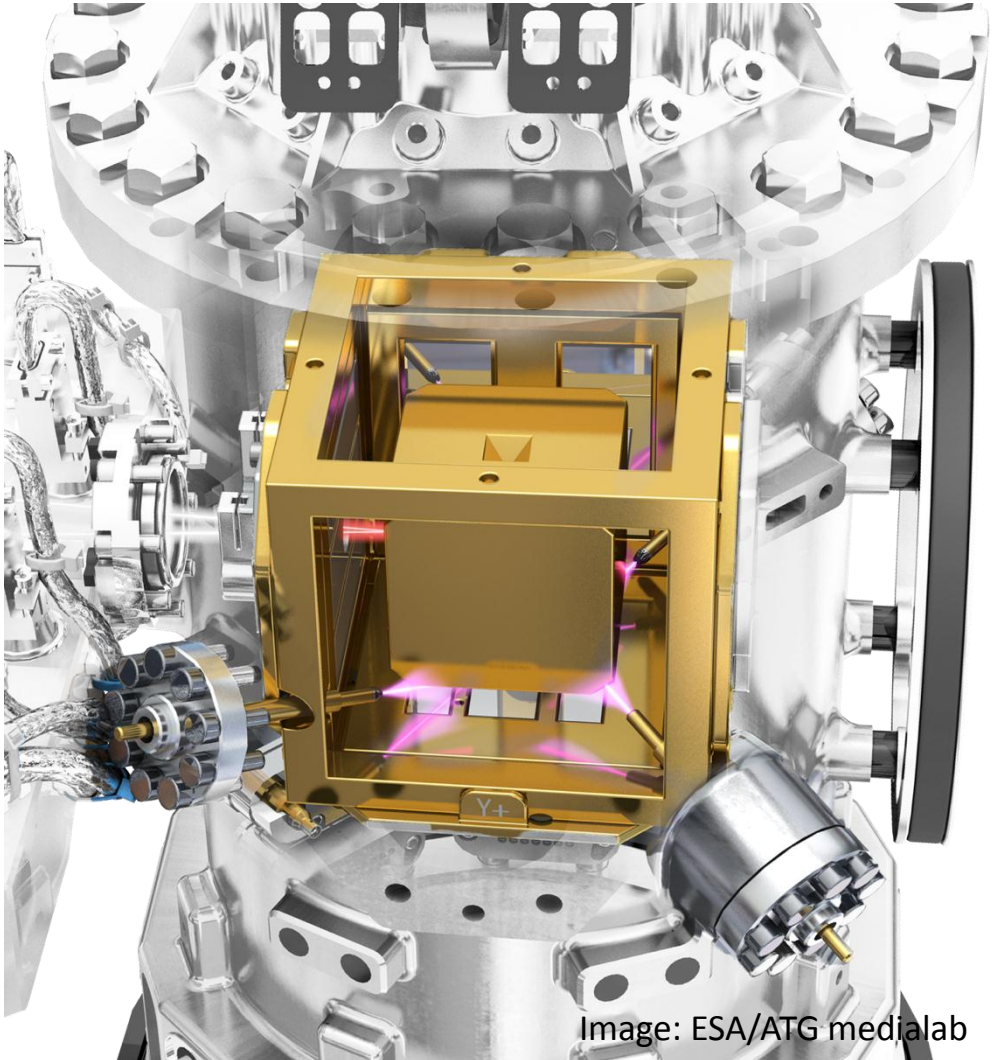

Image: ESA/ATG medialab

Hardware

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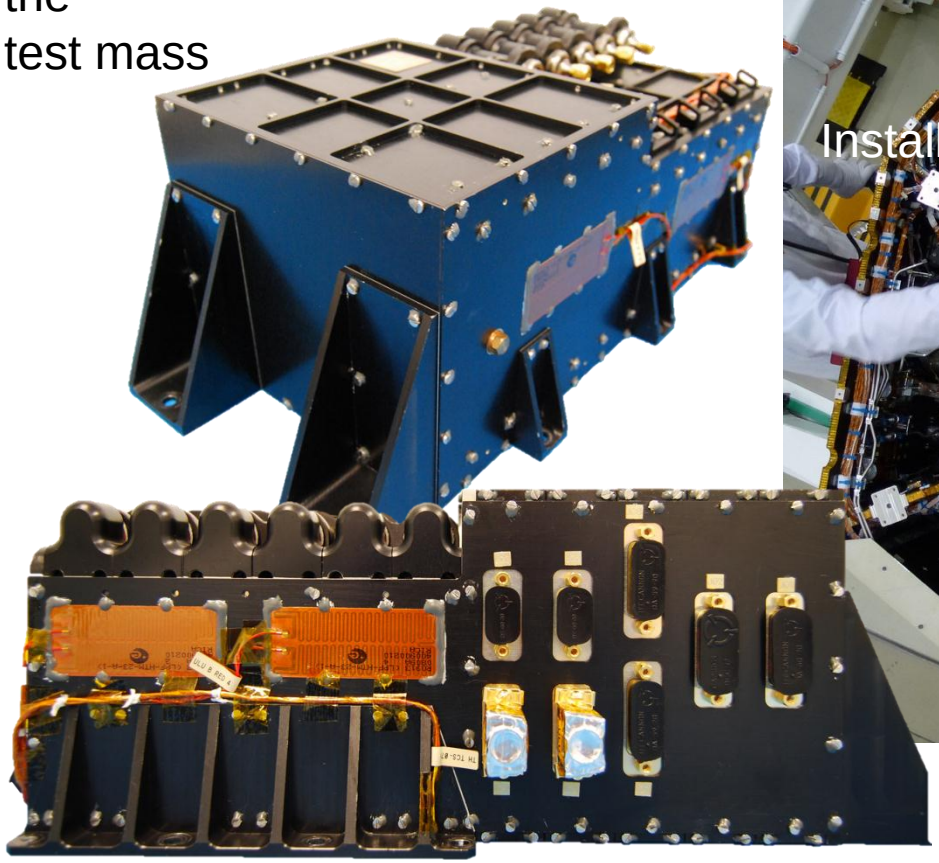
Designed and built a system of UV lamps and controlling electronics to generate light which will precisely control the charge on the
test mass



Installed on spacecraft at Airbus Stevenage

Operations

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- Demonstrate that the technology is capable of measuring gravitational waves
- Measure all effects that are limiting the performance
  - space craft magnetic field
  - stray electrostatic fields in the sensor
  - test mass charging from space environment
  - self-gravity of spacecraft
  - residual gas around the sensor
  - radiation pressure fluctuations from the laser
  - temperature gradients across the sensor
  - stability of applied voltages…

New Technology

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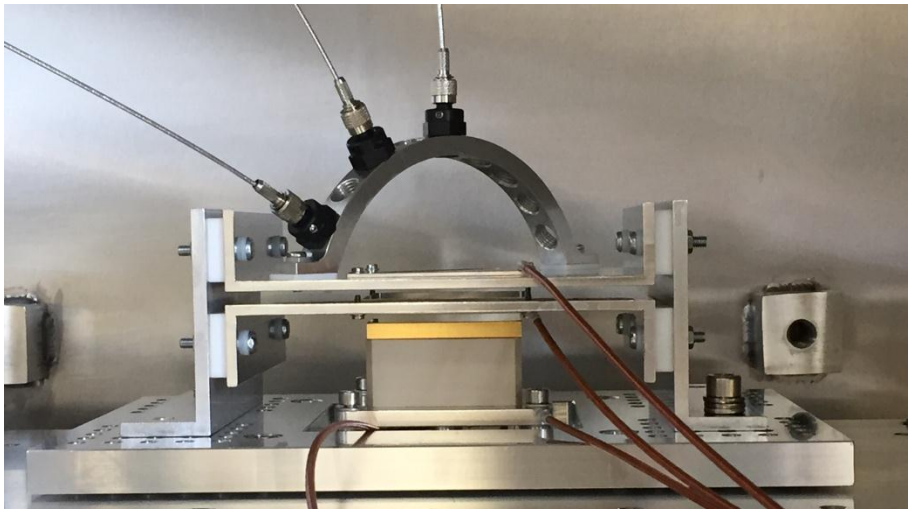
- LISA technology must be even more sensitive and stable than LISA Pathfinder
- Imperial leading the development of a new discharge system for LISA
- Based on new deep-UV LED technology
- Simpler to operate, more versatile, and efficient than lamps
- Physics of discharging



Headlines

- LISA Pathfinder will launch in November this year with Imperial Technology on-board and Imperial scientists leading data-analysis.
- LISA is an opportunity to observe the universe in a totally new way.
- Imperial and the UK are well placed to play a major role in LISA.

27 November 2015